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Prof. Edwin J. Houston, A.M., Ph.D., Chairman; Prof. Arthur Beardsley,
C.E., Ph.D., Mr. Theo. D. Rand, Prof. Coleman Sellers, E.D.,
Mr. J. C. Trautwine, Jr., Committee on Publications,
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THE MANUFACTURE OF VERY ACCURATE STRAIGHT EDGES.

BY F. L. O. WADSWORTH.

In the construction of mechanical or scientific instruments of precision, the problem frequently arises to provide means of guiding carriages through a considerable distance in as straight a line as possible.

Rectilinear motion may in general be secured by the employment of either link work or by the use of gibs or ways; but of these two methods the latter is by far the one more frequently adopted.

In the construction of the large "wave comparer," which has recently been used with such great success by Professor Michelson in his determination of the standard meter in terms of the wave length of light,* this same problem was presented, and the accuracy of movement demanded was considerably greater than is usually attained, even in the best comparators and measuring machines.

In this case the employment of link work was rendered impossible on account of the limited space at disposal, even granting that its employment would have secured the desired accuracy. The use of planed ways on the bed of the instrument itself, which in its general features resembled a long lathe bed, was equally inadmissible, because even if such ways could once be brought to the degree of straightness demanded, the initial strains in the casting would soon manifest themselves to such a degree as to render a resurfacing, or rather a restraightening, of the ways necessary whenever the bed was moved. For these and other reasons it was finally determined to secure the desired accuracy of movement by the use of steel straight edges as guides for the carriages; these straight edges forming no part of the bed itself, and being secured to it in such a way as to avoid as far as possible any distortion from a twisting or warping of the support.

The manner in which this was done is shown in *Fig. 1*, which shows the bed in cross-section. The main portion of the bed *a a* is of H section, and has planed upon it two ways *r r*, on which the outer edges of the two carriages *M N* rest and slide. On the central cross bar of the H rests a long cast-iron bar *b*, against which are lightly clamped the three steel blades *c c′ d*, four edges of which, viz.: the two edges of the horizontal blade and the two upper edges of the two vertical blades, form the inner ways for the carriages *M*, *N*, which move longitudinally along the bed, and are therefore guided in their movement by the two planed ways *r r* on the bed and the steel straight edges just referred to, the carriages being kept against the two vertical edges of *d* by the action of the inclined ways *r r*.

The actual problem was not, as might have been inferred from the preliminary statement of it, to have every point in the carriage move in a straight line; this would have necessitated that the outer ways *r r* be of the same order of accuracy as the straight edges, and this even if once secured would have been extremely difficult to preserve; but it was to have the carriage so guided that the plane of section perpendicular to the line of movement should always remain parallel to a given fixed plane, or in practice so that a mirror supported on the carriage with its face in this plane should always remain as nearly as possible normal to a ray of light whose direction is parallel to the direction of movement.

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* *Nature*, **49**, 60.

Now, it is evident from this disposition and arrangement of bearing surfaces, that any irregularity or want of straightness in one of the ways *r r*, will produce simply a rotation of the carriage in a plane perpendicular to the line of intersection of the planes of the two edges, and that granting only that each of these edges be straight any surface mounted on the carriage parallel to this perpendicular plane will remain parallel to itself for all positions of the carriage. It is not necessary, either that the ways *r r* be straight or parallel to the straight edges, or that these last be parallel to one another.*

The problem, from a mechanical standpoint, then reduced itself to one of producing four straight edges, of such an order of accuracy that the extreme angular movement of the carriage in moving from one end to the other of its ways should not exceed two seconds (2″) of arc, which means in linear terms that the error in any part of the straight edge should not be greater than $\frac{1}{100000}$ the length of the carriage (in this case seven inches), or about $\frac{1}{15000}$ of an inch. Although this was a rather high degree of accuracy for such long straight edges (51½ inches), it was hoped that the manufacturers would be able to make them of the required degree of accuracy by ordinary mechanical processes. After considerable correspondence, the work was intrusted to a well-known Eastern firm, whose reputation for this class of work is unexcelled in either this country or in Europe. In order, however, to check the results obtained by the manufacturers, as well as to afford a means of testing the edges after they were secured in place and at any future time during the use of the instrument, it was necessary to devise a method by which the edges might be compared with another standard edge; such, for example, as an actual metal standard, or a mercury surface.

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*A slight error is introduced on account of the finite width of the edges themselves, and the finite length of the bearing points, the bearing surfaces on the carriages being each about fifteen millimeters long, and of a width equal to the thickness of the straight edge; but the errors introduced by this cause are of the second order, as compared with the necessary irregularities in the ways themselves.

The construction of another standard especially for this purpose involved considerable expense, which it was desirable to avoid.

Besides, in order to insure that this reference standard itself retains its form to this degree of accuracy in all positions of its use, it would have been necessary to have made it too deep and stiff to have been conveniently used in the space between the vertical edges and the sides of the bed. The two horizontal edges, c, c', might have been compared with a mercury surface by the aid of a high-power microscope, a method used by Professor Rogers in surfacing the bed of the Rogers-Bond comparator, but it is difficult to devise any simple method for comparing a vertical edge with such a horizontal surface.

The method, proposed by Professor Michelson and used first in the process of examination and afterward, during the process of grinding, for measuring the errors of the edges and checking the grinding process, is an optical one, which has been found more convenient in practice and capable of giving more accurate results than the methods of this character which have heretofore been used. It is to the improved method of testing rather than to any improved method of working that the results which have been obtained are due, for in any method of working in which corrections are determined and applied with reference to a standard edge or standard surface, the accuracy of the result cannot, as a rule, exceed the accuracy of the standard.

In this case the reference edge, if such it may be called, which is used as a standard, is as near a geometrical straight line as it is possible to approach by any physical method, being what is termed a ray of light in the language of geometrical optics.

More explicitly stated, the method consists in projecting a parallel beam of light normally on the surface of a mirror, mounted on a carriage, which slides along the edge to be examined (the mirror being placed as nearly as possible at right angles to the edge), and measuring the angular deviation of the reflected beam as the carriage is moved along the straight edge.

The actual apparatus which was employed for the purpose is shown in *Fig. 2*. Light from the illuminated cross wires of an ordinary telescope focussed for parallel rays falls upon a plane parallel piece of glass *B*, by which a portion is reflected to the mirror *C*, mounted on the testing carriage, and forms, after nearly normal reflection from this mirror, an image of the cross wires at the focus of the observing telescope *D*, also carefully focussed for parallel rays. *D* is furnished with a micrometer eye-piece with double cross wires of the usual construction.*

a is an ordinary condensing lens, serving to concentrate the light from a lamp or gas flame on the cross wires of *A*.

Both telescopes being accurately focussed for parallel rays, and the telescope *D* being set so that its axis is in the prolongation of the straight edge under test and perpendicular to the mirror *c*, the glass plate *B* is adjusted until the illuminated field of *A* is central in the eye-piece of *D*.

The telescope *A* and the micrometer eye-piece are then rotated until the cross wires of each are parallel to the plane of the edge to be tested. The carriage is then placed at one end of the edge and the wires of *D* set so that they are just bisected by the image of the horizontal cross wire of *A*. Then if the edge be perfectly straight it is evident that the relative position of the micrometer wires and this image seen by reflection from *c* will remain the same for all positions of the carriage, but that any elevation or depression will at once cause a deflection of the image, the amount of which is accurately measured by the micrometer. The possible delicacy of the method is limited only by the size of the telescopes employed, provided only the mirror *c* be of the same size as the object glasses.

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* For the sake of avoiding confusion in the measurement it is a good plan to cut out the ordinary fixed wires and retain only the double movable ones.

An objective of quite moderate size is, however, sufficient. The dimensions and constants of the apparatus used in the present case were as follows:

Aperture of telescope, ...	40 mm. (1·6″)
Focal length of telescope, ...	314 mm. (12·3″)
Constant of micrometer, ...	1 div. corresponds to $\frac{1}{200}$ mm.

A deflection of the image through a distance of $\frac{1}{200}$ mm. at the focus of the observing telescope, corresponding to one division of the micrometer head, meant therefore an angular deflection of the beam of light of 3·2″, and therefore since the deflection of the beam of light is doubled by reflection, an angular deflection of the carriage and mirror through about 1½ seconds (1½″).

This constant can be and was measured directly in at least two other ways: (1) By inserting a strip of mica of measured thickness under one end of the carriage, and measuring the deflection produced, and (2) by displacing the cross wires of the first telescope through a known angle by means of the divided circle of the spectroscope table on which it was mounted, and measuring the corresponding deflection. The mean angular value (for the carriage) for one micrometer division, as found by all these methods, was for the apparatus used about 1·5″, corresponding to a displacement of one end of the carriage through about $\frac{7}{150000} = \frac{1}{21000}$ of an inch. One division of the micrometer head corresponded then to about the limit of accuracy imposed. The resolving power of the telescope employed was such that differences of at least one-fourth this amount could be measured with certainty;* indeed, readings were always made to tenths of a division, two successive readings rarely differing by more than 0·2 div. from one another.

A fairly typical set of readings taken during the process of grinding one of the edges is given in the following table. Here the two readings corresponding to the same position of the carriage were not taken successively, but form two of a continuous set beginning with No. 1, and ending with No. 14, according to the method of testing presently to be described. Added to the error of reading we have then the errors due to accidental particles of grit getting under the carriage between two readings, the error, if any, due to the movement of the carriage in opposite directions, and the error due to systematic changes in any part of the observing apparatus..

TABLE I.

No.	Reading.	No.	Reading.	Mean of Two Readings for Same Position of Carriage.	Differences from Mean.	Mean Error.	Probable Error of Single Setting.
1	14·7	14	15·0	14·85	·15	From 14 observations = ·2 div.	As determined from 14 observations $\epsilon = \cdot 61 \frac{\sqrt{\Sigma \theta^2}}{\sqrt{\pi - 1}}$ = ·16 div.
2	15·3	13	15·0	15·15	·15		
3	15·0	12	15·2	15·40	·20		
4	14·1	11	13·5	13·80	·30		
5	15·0	10	15·0	15·00	·00		
6	13·7	9	14·4	14·15	·35		
7	14·0	8	14·6	14·30	·30		

When the bar was approaching completion considerably greater care was taken in cleaning the surfaces before testing, and the results were then considerably better; for comparison a set of readings under these more careful conditions of testing is given in Table II, which shows that we may rely on the correctness of the indicated error to at least 0·1 div., that is to about $\frac{1}{200000}$ inch.

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* Resolving power as ordinarily used is defined by the relation $\varepsilon = \lambda/\Delta$ where ε is the smallest angle which can be "resolved," or the angle as viewed from the objective between two fine lines or points so close together as to be just distinguished apart: λ the wave length of light, and Δ the diameter of the objective. In this case $\varepsilon = \frac{\cdot 00055}{40 \cdot 5} = 2 \cdot 5''$, a quantity considerably greater than it was stated it was possible to distinguish. It must be remembered, however, that it is easier to distinguish differences between two successive positions of a single object than to determine whether two bright objects placed close together are separate or not, because in the one case there are two sets of diffraction fringes which overlap and cause confusion, and in the other case only one set whose position has only to be judged with reference to some fixed object (in this case the cross-wires) so far distant from it that no overlapping and consequent confusion results.

TABLE II.

Edge No. 1, final.

No.	Reading.	No.	Reading.	Mean of Two Readings for Same Position of Carriage.	Difference from Mean.	Mean Error.	Probable Error of Single Setting.
1	37·2	16	37·6	37·40	·20	Mean error of these 16 readings 0·07 div.	Probable error of single setting $= \cdot 67 \frac{\sqrt{\epsilon\ \theta^2}}{\sqrt{\pi - 1}}$ = 0·06 div.
2	37·5	15	37·6	37·55	·05		
3	37·3	14	37·2	37·25	·05		
4	37·8	13	37·7	37·75	·05		
5	36·8	12	36·7	36·75	·05		
6	37·2	11	37·2	37·20	·00		
7	37·3	10	37·1	37·20	·10		
8	37·0	9	37·1	37·15	·05		

When the finished straight edges arrived, each one was set up with its edge horizontal, being supported in position by two wooden supports, as shown in *Fig. 2*, placed about one-fourth the length of the bar from each end. One of the four-inch straight edges, No. 1 (*Fig. 1 c*), was first tested and was found to fall so far below expectations that we determined to attempt the correction of it ourselves by grinding down the edge with fine emery. Three grinding tools were therefore prepared, of the form shown in *Fig. 2 A*, of different lengths, one being about twelve inches long, another seven inches, and the third about three inches long. For the purpose of approximately determining the amount removed, a fine micrometer screw, with a large divided head, reading to $\frac{1}{1000}$ mm. $= \frac{1}{25000}''$ was mounted so as to be used as a beam caliper, but it was found that after a little practice with a given grade of emery it was possible to judge very closely of the amount removed by the time of grinding and the pressure used. Besides, the process of testing is so rapid that the whole operation of observing, reducing results, and plotting the curve requires on the average less than ten minutes, and it is, therefore, better to determine the complete curve for the edge after each grinding. The routine method of doing this was as follows:

The carriage was placed first with one end coinciding with the end of the straight edge, and the reading of the micrometer taken; it was then moved forward its own length and another reading taken, and so on to the end. A similar set was then taken going in the reverse direction, and the mean taken of the two readings (going and coming) for the same position of the carriage, as has already been indicated in Tables I and II.

From this set of means the curve was plotted as follows: The difference between each reading and the next successive one, when multiplied by a factor depending on the constant of the micrometer and the length of the carriage, will evidently represent the difference in level between the two ends of the carriage in the second position, as referred to the line of reference, viz.: the direction of propagation of the incident beam of light. If then these differences be successively added and the numbers so obtained plotted as ordinates to a curve whose abscissæ are distances along the straight edge, the resulting curve will be that of the edge in question. For convenience in plotting, the differences are taken not between successive readings beginning with the first (although this was the plan first adopted), but between each reading and the general mean, the object being to make the ends of the bar coincide with the axis of plotting, and at the same time furnish a check on the numerical reduction of the observations. The following set of readings, Table III, will serve as an example of this method of reduction, the readings being those made on the first straight edge tested (No. 1), just as it came from the makers.

TABLE III.

No.	Position on Bar.	Mean "Going" and "Coming."	General Mean.	Difference.	Σ differences = y	$y' = ·00007 \times y$ Difference of Level (Inches).
0	0	—	190·4 ÷ 7 = 27·2	—	0·00	·00000
1	7 inches	29·5	27·2	— 2·3	+ 2·3	·00016
2	14 "	30·5	27·2	+ 3·3	— 5·0	·00039
3	21 "	28·5	27·2	+ 1·3	+ 6·9	·00048
4	28 "	25·5	27·2	— 1·7	+ 5·2	·00036
5	35 "	25·8	27·2	— 1·4	+ 3·8	·00027
6	42 "	25·6	27·2	— 1·6	+ 2·2	·00015
7	49 "	25·0	27·2	— 2·2	+ 0·0	·00000
		190·4				

As seven-inch intervals on the bar are too great for accurately determining its form, an intermediate set of readings was then taken, beginning at a distance from the end equal to one-half the length of the testing carriage. This set, repeated in return as for the first set, was then reduced independently in the same manner and plotted with the first. As the second series of points so obtained is not necessarily referred by the process of reduction to the same axis of abscissæ as the first, it is generally necessary to adjust the second set with reference to the first either by an elevation, depression or rotation of this axis. Usually a simple inspection would show which of these three operations was necessary.

For example, in the case of the bar just cited the readings at the intermediate points were as follows:

TABLE IV.

No.	Distance from End.	Mean of "Going" and "Coming."	Differences.	Σ Differences $= y$.	$y' = y \times$ ·00007.
0	3½″	—	—	000	·00000
1	10½″	29·5	+ 2·4	+ 2·4	·00017
2	17½″	29·5	+ 2·4	+ 4·8	·00034
3	24½″	27·8	+ 0·7	+ 5·5	·00038
4	31½″	25·4	— 1·7	+ 3·8	·00027
5	38½″	26·5	— 0·6	+ 3·2	·00022
6	45½″	25·6	— 1·5	+ 1·7	·00012
7	End	25·2	— 1·9	— ·2	·00001

This series of points is plotted in *Fig. 3*, together with those of Table III.

If the curve were drawn through both sets of points at once as they stand, it would present a series of waves of regular period (as shown by the dotted curve) which there is no reason to suppose exist.

If we simply rotate the second system of points about the point *a*, we find that every point of the second system will fall nearly upon the curve drawn through the first set, the outstanding differences being such as we might readily suppose to exist.

The most probable general form of the edge as determined from these two sets of observations, at three-and-one-half-inch intervals may, therefore, be considered to be represented by the heavy line, *Fig. 3*. It would, perhaps, be better to use a carriage only as long as the shortest testing interval, were it not for the fact that in the first stages of the correction it is not necessary to take intermediate points, and the process of testing at seven-inch intervals is much more rapid than that at three-and-one-half-inch intervals with the shorter carriage. It would be best for this reason to have two carriages, one, say, of seven, the other of three and one-half inches length, the former to be used in the first stages and the latter in the final stages of the testing. The shorter the carriage, too, the greater the accuracy attainable with a given size of mirror and telescope. Although the shortest interval at which observations were plotted was three and one-half inches, the observations were in a sense continuous from one end of the bar to the other, for the motion of the carriage was so smooth that the motion of the image in the micrometer eye-piece could be observed during the motion of the carriage. If any sudden deflection was observed between two points of observation, that particular part of the edge was always subjected to an examination at much shorter intervals.

The method of grinding, however, was such that the introduction of any irregularities of short period was extremely improbable, and, in fact, except in a few exceptional cases, such sudden changes were never observed.

The general process of grinding down the edge was to select (after each test had been made) a grinding tool corresponding to the character of the irregularity and a grade of emery corresponding to the amount to be removed, and grind away at the high places a length of time depending on the judgment of the operator. The edge was next very carefully cleaned by first washing thoroughly with coal oil or benzine, polishing with a piece of fine crocus cloth to remove any edge burr that might have been raised during the grinding, and finally rubbing the surface with a piece of linen or, better, chamois cloth. The bearing steps of the testing carriage were also carefully cleaned and the carriage placed in position and passed back and forth from one end to the other several times until not the slightest feeling of grinding or roughness due to any minute remaining particles of emery or dust could be detected.

When properly cleaned and polished the carriage ought to "float" on the edge almost as easily as one well-made surface plate on another. When this cleaning is properly performed the readings "going" and "coming" for the same position of the carriage agree with each other and may, as already stated, be depended on to 0·1 div. of the micrometer head.

The process of working down the edge by this process, successively testing and grinding, is very rapid, provided the material of which the edge is made is uniform and homogeneous, and, what is still more important, free from initial strain due to hammering or rolling. The characteristic successive steps in working down the edge first taken are shown in *Fig. 4*, *a*, *b*, *c*, etc., the final stage being represented in *Fig. 4*, *d*, an inspection of which will show that the maximum error remaining was less than $\frac{1}{250000}$ inch, an error considerably less than the limit imposed.

This was so encouraging that the remaining edges were corrected in the same manner.

Edge No. 3, the next one taken in hand, is represented in its initial state in *Fig. 5*. As will be seen, it was considerably better than edge No. 1, but that the errors were considerably larger than could be allowed. In the process of working down this edge an unexpected difficulty presented itself—a difficulty due probably to a want of proper annealing of the steel bar of which the straight edge had been made. During the grinding the bar changed its form repeatedly, the changes observed between two successive grindings being far greater than could have been caused by the simple removal of too great an amount of material at local places. Another curious thing was that the local grinding of a high spot seemed in many cases to increase rather than diminish the error at the point of grinding; in other words, the metal seemed to swell up under the action of the grinding tool. Then, after a series of successive attempts to reduce the "hump" with very little success, the material seemed suddenly to give way all at once, and a deep hollow was the result. The grinding down of the extreme ends was a matter of special difficulty, as the springing there was especially bad. It seemed almost impossible to attain as high a degree of accuracy in this case as in the preceding, and after spending a good deal of time on the bar it was finally left in the state shown in *Fig. 6*, with the intention of making the final corrections after it had been clamped in place, hoping that the clamping might prevent the springing which proved so troublesome.*

The correction of edges Nos. 2 and 4, the opposite edges of the one bar *c*, proved the most difficult task of any. The warping, presumably on account of bad annealing, was specially bad, and working on either edge almost invariably affected the form of the other, so that it was necessary to reach the final result by a series of successive approximations, working first on one edge until it was nearly right, then on the other, then on the first again, and so on until the amount to be taken off from each side was so small that its removal did not affect its neighbor.

It was necessary also to make a specially light bronze testing carriage for this bar, in order to avoid errors due to the deflection of the bar by the weight of the carriage, errors for which it is true allowance might have been made, but which it seemed better to avoid if possible.

The deflection of the bar due to its own weight here becomes of importance.†

It was reduced as far as possible by placing the supports about one-fourth the length of the bar from each end, under which conditions the deflection at the centre is only about one-fortieth that experienced when the bar is supported at

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*It must be remembered that the movements observed are, after all, extremely small, the springing rarely amounting to more than ·00005 inch, and usually much less.

† The deflection of a uniform bar supported at its ends is

$$\triangle = \tfrac{5}{32} \frac{s\ l^4}{E\,d^2}$$

where s is the weight of the bar per cubic inch, l the length (in inches) and d the depth. In this case assume $E = 25{,}000{,}000$. $\triangle$ is found to be ·0027 inch, a quantity corresponding to about fifty div. of the micrometer.

the ends. This slight outstanding error was in the first stage of the correction neglected, as it was intended to make the final correction *in situ*, thus eliminating at once all errors due to flexure. The initial curves for edges 2 and 3 are given in *Fig.* 7, the final curves in *Fig. 8*.

This work was mainly for the purpose of obtaining some idea of the capabilities of the method and determining the limit of accuracy which it was practically possible to obtain without too great an expenditure of time and labor.

As regards the first point, a glance at the final curves will show that the extreme error for edge No. 1 was, as has already been stated, less than $\frac{1}{25000}$ of an inch, for edge No. 2 it was less than $\frac{1}{40000}$ of an inch, and for edge No. 4 about the same as for No. 2. In the case of No. 3, the error is considerably greater than this, on account of the special difficulties already mentioned. As regards expenditure of time, these results were reached in eight days (February 16th to February 24th), an average of only two days' work for each edge, which, for the degree of accuracy obtained, cannot be considered extravagant.

It was fortunate that no more time was spent in an attempt to secure a greater degree of accuracy, for the changes which the bars experienced either during the setting up of the instrument or during its transportation across the ocean, were very much greater than had been anticipated. A preliminary test of the straight edges, after their arrival in Paris, showed that they were very badly warped, indeed, one of the edges being out nearly ·0004 of an inch.

Notwithstanding the comparatively large amount of material which it was necessary to remove, it was determined to this time do *all* the grinding while the edges were firmly clamped in their final position, in hopes that this clamping might prevent the springing of the steel bars, which had before proved so troublesome, especially with edges Nos. 2, 3 and 4.[*]

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[*] The author is now of the opinion that if most of the material had been removed while the bar was free, many of the difficulties encountered in the final stages of the work would have been obviated.

The clamping screws having been screwed firmly down, a second test was taken, and showed that the form of the edges had not been materially changed by the clamping action. The testing carriages used were now the actual carriages to be used in the final work, a mirror being mounted on each one in such a way that any one of the four edges could be tested without moving the optical part of the testing apparatus. An innovation was introduced in the way of grinding tools, which was in many respects a step backward.

Instead of the iron grinding tools already described, a number of rectangular blocks of emery, of different lengths and of varying degrees of fineness, were prepared. To protect one edge from the action of the grinding block while the adjacent edge was being worked upon, one side of the block was covered with paper.

The reduction of the large irregularities was performed by the mechanician of the laboratory, but in the final stages of the work it was found necessary to return to the iron grinding tools previously used.

After the edges had been brought to about the condition shown in *Fig. 5*, we took the grinding in hand ourselves, and in a few days, with the experience already acquired, brought the edges to their final condition, shown in *Figs. 9, 10, 11, 12*.

The difficulties encountered in this work were greater even than had been experienced in the course of the work on the free bars. In the first place, the initial strain in the bars was not allowed to manifest itself freely as before, on account of the clamping action of the screws, which was not, however, great enough to entirely prevent what seemed to be a gradual or often sudden "creeping," which proved very troublesome. Moreover, the work on any one edge was almost certain to affect the trueness of the adjacent edge, so that, in this case, all the edges had to be reduced by the process of approximation, which has already been referred to as necessary in the previous work, in case of edges Nos. 2 and 4, some of the individual steps of which were more satisfactory as regards a single edge than the final result for that edge. It is especially worth noting, however, that all, or nearly all, of the difficulties encountered were due to the bad material, or rather the bad state of the material, of which the bars were made. Had the steel been uniform in texture, and either thoroughly hardened and seasoned or thoroughly annealed, the time required to complete the work would have been reduced one-half, and probably more. Even in the state of strain, however, there was no difficulty in reducing the errors of the edge to an order of $\frac{1}{5000}$ inch. An hour or two hours' work usually sufficed to bring about this order of accuracy when the initial error was from five to ten times this amount. The time taken to bring all four edges to their final state, as shown in *Figs. 9-12*, was between 40 and 50 hours, an average of from 10 to 12 hours' work on each edge. As will be seen by inspection, the accuracy is rather greater, on the whole, than was attained in the first work, the greatest absolute error for two of the edges, at least, being not greater than $\frac{1}{50000}$ inch, with a mean error of less than $\frac{1}{100000}$ inch in the whole length of 52 inches. To make a straight edge of this length accurate to this degree, by the ordinary method, would require an expenditure of time which would render it impracticable as a commercial operation. The results of the preceding work, however, show conclusively that, with suitable material, such edges may be prepared from the planed bar at an expense (for labor) not exceeding $3 per foot of length for edges, four feet long, accurate to within $\frac{1}{50000}$ inch for their whole length.

For longer edges the cost would probably be somewhat less, for shorter ones somewhat more per foot of length. *There is no limit to the length which may be made straight to this order of accuracy quite without reference to any material standard*, an important consideration when it becomes a question of making standards six to ten feet in length.

Errors due to flexure are corrected in the process itself, it being only necessary that the edge be tested when supported in the same manner and the same position in which it is to be used. This allows the use of comparatively light bars instead of the deep girder forms necessary when the ordinary method of correction by working three edges to one another is used, a process which requires that at least two of the bars be stiff enough to avoid a perceptible change of form when turned upside-down, a condition very difficult to secure when the bars become of unusual length.

It is difficult to see what obstacles remain to be overcome in the successful application of this method to commercial work, except the single one of obtaining homogeneous and well-tempered bars of metal upon which to operate. As has been seen, it is possible to produce straight edges of the order of accuracy herein stated rapidly and cheaply, even when the material is not properly prepared, but these edges are not sufficiently permanent under handling to warrant their being brought to such a degree of accuracy unless they are to be permanently clamped in place.*

Given a bar of proper material, it may be confidently stated that straight edges of from five to ten feet in length, or even longer, if desired, may be produced with an error not exceeding $\frac{1}{1000000}$ inch in their whole length. The same method may be applied also to the correction of the ways of measuring machines, dividing engines, comparators or any apparatus in which a very accurate rectilinear motion is to be secured. To these last purposes it is especially applicable, as it allows the testing to be made and the corrections to be applied in any desired position of the edges or ways upon which the work is being done, which renders it possible and practicable to always correct the ways when the bed which supports them rests in the position which it is destined finally to occupy, compensating then at once for all the effects of flexure due to want of rigidity, and twist or other distortion due to the manner of support.

To sum up briefly, the principal advantages which the method seems to possess are:

(1) Possibility of producing one edge, and one edge only, of any required length and of any required order of accu-

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* There has been no perceptible change in the edges since they were first finished, which, at the date of writing, was over six months ago, during which time the instrument has been in use almost continuously.

racy, without reference to any previously existing edge or material standard.

(2) The possibility of measuring definitely the errors in this edge and mapping them for future reference, so that it will not be necessary to carry the work on any edge further than the desired order of accuracy.

(3) Ability to test and correct an edge in any position, and to readily verify its correctness at any future time, recorrecting it if necessary without removing it from position.

(4) Rapidity and cheapness in securing a desired result.

This last is an important practical advantage which leads me to hope that the article may not be without interest to the intelligent mechanics and instrument-makers of this country, who are always ready to adopt any practical methods which will lead to greater accuracy in the production of certain classes of high-grade work.

A number of modifications of the general method which may prove serviceable in certain cases may be proposed. Those familiar with the optical arrangements will at once see that instead of two telescopes, arranged as shown with the glass *B*, all that is absolutely necessary is a single one, occupying the position of *C*, and provided with a pair of illuminated cross-wires, the image of which will be seen in the field of the eye-piece when the telescope is focussed for parallel rays and the mirror is nearly perpendicular to the axis of the telescope. The deflection of the image from the cross-wire itself might be measured as before, or perhaps even more simply by the aid of a fine scale in the eye-piece. As it is desirable for the sake of accuracy to use a double movable wire to fix the position of the deflected image, and as it is also desirable to be able to move the set of wires whose image is observed without moving those in the micrometer eye-piece, a better arrangement would perhaps be that shown in *Fig. 13*. Here the illuminated cross-wires are placed at the end of a short tube *b*, placed at right angles to the axis of the telescope. At *c*, the intersection of the axis of *b* with the axis of the telescope, is placed either a plane parallel glass at 45° covering the whole field, or a small right-angled prism covering one-half the field. *D*, as before, is simply a condensing lens which serves to concentrate the light on the cross-wires in *b*. With this device the whole arrangement is rendered very compact and convenient to use, as both sets of wires are close to the observer. Means might easily be provided by which the observer could himself move the carriage along the bar to any desired position without leaving his seat; but as the one who is doing the grinding is always at liberty during the operation of testing, the necessity for such a device is obviated.*

For horizontal edges and ways, a somewhat simpler method may sometimes be used. Instead of measuring the deflections of the testing carriage optically, they are measured by means of a delicate level which is secured to it. Level bubbles can now be obtained so sensitive that one division on their scale corresponds to one second, and as one-half a division is easily read with certainty, it follows that for a carriage of the same length deflections nearly as small as those measured optically may be determined more directly in this manner.

By mounting the level as shown in *Fig. 15*, it would be possible to examine edges inclined at any angle in a vertical plane; but as the method is a gravitational one, it fails for all edges out of this vertical plane.

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* It is usually best to have two persons in doing the work, one of whom attends to the grinding, the other to the testing. One observer, however, can easily test as rapidly as three or four can grind.

The usual method of optical testing is to place a telescope on the carriage which moves on the straight edge, and direct this telescope either at a very distant object, or better, at the cross-wires of a second collimating telescope placed in line with the straight edge as shown in *Fig. 14*.

We can then observe in either telescope (their axes being now in the same straight line) the movement of the image of the cross-wires of the other as the carriage is moved along.

The primary disadvantage of this method is that it makes the testing carriage much heavier than the mirror does, a very serious objection when great accuracy is demanded. Then, for a given size of telescope it is only one-half as delicate as the mirror method, as the angle through which the image is deflected is, in this case, the same as that of the carriage, instead of double that angle as in the case of the mirror method.

SUPPLEMENT.

Aside from its applications to the mechanical operations already indicated, the optical arrangement described in this paper would be admirably adapted to the experimental investigation of certain problems connected with the theory of elasticity.

Formulæ for the elastic curves of beams and columns under different conditions of loading have been worked out for a great many cases, but, as far as I am aware, no complete experimental verification of any of these formulæ has been made.

Such a verification, aside from its interest on purely theoretical grounds, affords data for the determination of E, the coefficient of elasticity. This coefficient is often obtained by measuring the bending of a bar supported at the ends by a considerable weight supported at the center, the deflection due to the weight being measured by the aid of a micrometer microscope. This method involves the use of quite as much apparatus as the one which is here proposed, and which gives us, in addition to the absolute deflection at the center, knowledge of what is going on at all parts of the length.

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ON GAS BURNERS, GAS PRESSURE REGULATORS AND GOVERNOR BURNERS, GAS GLOBES AND GLOBE HOLDERS, AND GAS FIXTURES.

BY WM. PAUL GERHARD, C.E.,
Consulting Engineer for Sanitary Works, New York City.

[*Concluded from Vol. cxxxvii, p. 421.*]

IV.—GAS FIXTURES.

A few remarks regarding the choice of proper *gas fixtures*—not from the artist's or decorator's point of view, but from the gas engineer's standpoint—may prove useful to the gas consumer; for oftentimes ill-contrived, poorly constructed or defective chandeliers or bracket fixtures are the cause of deficient interior illumination.

Manufacturers of gas fixtures, with rare exceptions, do not pay much attention to the essential requirement of correctness in mechanical execution. The designs of fixtures which they offer may be exceedingly pretty, neat and decorative, but fixtures with too much scroll work often turn out to be quite objectionable, where the gas supplied to the house is improperly purified, or where the distributing pipes for gas are pitched toward the chandelier or bracket, or where the drop is taken directly from the bottom of a line, in which cases the fixtures in a short time accumulate much watery vapor or napthaline, which hardens in the tubing and obstructs the passages for gas.

Firms engaged in the manufacture of fixtures often employ artists at a high salary to design novel forms of expensive gas fixtures, but who has ever heard of a firm engaging a competent mechanical expert, thoroughly conversant with the requirements to be observed to obtain the best illumination and the highest degree of light, to make details for the mechanical execution of the work and to advise on the best kind of burners and globes to be used?

Faulty mechanical execution is by no means confined to the cheap class of fixtures. Even the best and most expensive modern fixtures are susceptible of much improvement in these respects.

One serious fault is the use of too small gas tubing in the fixtures, through which the requisite volume of gas to supply the burners cannot pass. It is quite common to find gas chandeliers with six or eight lights constructed of one-quarter inch tubing. A simple calculation shows that a one-quarter inch pipe, ten feet long, is only capable of supplying 5·7 cubic feet of gas per hour at four-tenths inches of water pressure; hence the tubing would be just large enough to supply one five-foot burner instead of six or eight. It would be quite useless to use on such fixtures any type of improved governor burner.

It is obvious that where pains are taken to pipe a house for gas with all service and distributing pipes of sufficiently large calibre, it is equally desirable to have the passages for gas in the fixtures of ample bore; in other words, the main tube of a chandelier should be of such a diameter as to be able to pass the necessary volume of gas required by the total number of burners on the fixture, all of which may be lighted at one time; and again, the side tube for each light and the bore of the gas key should be of such a diameter as to afford passage for an adequate volume of gas to each burner.

All gas keys of fixtures should be made strong and of full bore; they should be ground with care, so as to be tight-closing, yet easily turned. A serious defect inherent to many fixtures is the leakage at the stop-cock, caused either by defective workmanship or by keys getting worn out or becoming honeycombed or loose. It is, in most cases, a matter of impossibility to apply any pressure test to the gas pipe system of a house while the gas fixtures are connected, as they usually leak at the fixture joints, at all swing joints of brackets, at extension pendants, and at the gas keys, much more than at the pipe joints.

It should, therefore, be made a rule that all large or heavy chandeliers should be tested before they leave the factory, and their tightness should be guaranteed by the makers when the fixtures are sold.

The hanging or putting in position of the gas fixtures should properly belong to the gas-fitter who piped a building for gas. It has, however, become the universal custom to leave this work to the gas fixture dealer or manufacturer, and it is a common experience that the fixture joints leak more or less when the gas is turned on for the first time at the meter.

The mechanic who does this work should use the utmost care to make the joints absolutely tight, and he should furthermore see that the joints do not become partly obstructed by bits of white lead squeezed out at the inside of the joint.

It is customary that the fixture dealer or manufacturer provides the gas fixtures with burners, and from personal observation and experience I can state that gas-fitters and gas fixture men take scarcely any interest whatever in the kind of burners which they put on fixtures, except that in some instances they may select burners the flames of which will not crack the globes. The bulk of the gas-consuming public are indifferent to the matter, and so we find in practice that even the most elaborate and expensive gas fixtures are provided with only the cheapest and most ordinary kind of burners, and often with badly-proportioned glass globes and cumbersome globe holders. The same size of burner tip is used without regard to the amount of light required in various rooms. The burners are carelessly put on and the gas passages are often partly choked with white lead.

It is far better to buy gas fixtures without gas burners and glass globes, and to purchase separately the very best kind of burners, and to insist on the use of globes with wide bottom opening, supported by shadowless wire prong holders.

Although good burners cost considerably more than the common bad ones, the extra price paid is more than compensated for by the yielding of a more satisfactory light, and by the saving in the gas bill. Some of the governor burners mentioned heretofore are the best obtainable burners and deserve unqualified commendation.

Old-fashioned gas fixtures are often quite defective, and may even become dangerous by reason of having so-called "all-round" keys or taps which are not made with stop pins. It is a frequent experience, particularly in lodging houses and hotels, that gas leaks, or even cases of asphyxia by inhalation of escaping illuminating gas are caused by the incomplete turning of these all-round keys, or by the accidental turning on of the gas after the extinguishment of the light.

Every now and then, in the course of my professional travels, I come across even first-class hotels having gas fixtures in the guests' rooms which are dangerous on this account, and I likewise find such fixtures with gas keys without stop pins in private houses, particularly in out-of-the-way places, in the cellar, in housemaids' closets, or in servants' bedrooms, where their use is attended with considerable risk. I have, years ago, argued that the use of such fixtures should be prohibited by act of Legislature. It is at least to be hoped that when the time arrives, when building departments will look after the gas piping in houses and exercise a supervision over the gas fixtures, similar to the supervision now enforced in sanitary matters and about plumbing fixtures, they will pay some attention to the above-mentioned defects, with which underwriters have long been familiar.

The modern fixtures are always provided with stop pins, but the metal of which they consist is often much too light, and after some use the pins crack off or bend out of shape. The remedy consists obviously in having all check pins attached to gas keys made of good size and extra strong and to have them well fastened.

Gas-escapes frequently occur with water slide chandeliers, when the water which seals the joint evaporates. The leakage of gas can be avoided either by frequent additions of water, or by putting on the water some sweet oil or glycerine, which retards the evaporation. While water joint pendants are quite common in England and on the Continent, they are not much used in our country, where either cork slide pendants or telescopic extension joint chandeliers are preferred, which dispense entirely with the chain and counterbalance weight and the water seal.

Gas fixtures may be divided into fixtures hung on side walls, or bracket lights, fixtures hung from the ceiling, called drop-lights, pendants and chandeliers or gasaliers, and portable gas fixtures.

Bracket light fixtures may be either stiff brackets, or horizontal swing brackets, with one, two or three joints, or brackets with parallel motion, as used for reading lamps, or for ophthalmoscopic purposes.

The drop lights with one or two arms are usually called pendants, whereas those with three or more lights are called chandeliers. Drop lights with single center lights are sometimes termed "lyras" or hall lanterns. The ceiling joint of such fixtures may be a stiff joint, a hinged joint, or a swing joint. Larger and heavier fixtures are hung with universal ball and socket joints. Chandeliers are often provided with extension fixtures, to pull down, and the joint in these is either a cork or telescopic joint. If the whole chandelier can be lowered, the fixture is hung with counterweights and the joint has a water seal (hydraulic gasalier).

Each burner is usually controlled by a separate gas key, except in rare instances, such as the incandescent "Beacon" lights, the sunburners and the multiple high power flame lamps.

I will close this article with a few remarks regarding the gas fixtures to be used in an average dwelling house.

Much of our life is necessarily spent by artificial light, in business, social and educational pursuits. In dwelling houses, in particular, much of the home comfort after darkness sets in will depend upon the arrangement and distribution of the gas lights.

It is a good plan to mark all the lights on the house plans at an early stage of the construction of the building. It is also desirable that all doors be shown on the plans and the direction in which they swing when opened, so as to avoid the frequent mistake of placing gas lights where the door would open against them.

It is well to fix at once, when locating the gas outlets, upon the height of the same. This depends to some extent upon the design of the fixture used. Where fixtures are intended for gas only, it is usually safe to place the side outlets at a height of five and one-half feet from the finished floor in all rooms, and six and one-half feet in all halls and passages except where the ceilings are very low, in which case there should be at least two feet between a gas flame and the ceiling (three feet would be still safer). Where combination electric and gas fixtures are used, the gas light is always placed uppermost, while the electric glow lamp hangs down or is placed inclined and pointing downwards. In that case the gas outlet requires to be put higher than usual to avoid exposing the glow lamp to breakage.

It is equally important not to place the lights on chandeliers too high, as it is not the purpose to illuminate the ceiling. In those rooms where a large center-table is placed permanently under the chandelier, such as the sitting-room, the library and the dining-room, the chandelier should be hung low so as to get a brilliant light on the table. The usual height of gas light on such chandeliers is six feet four inches from the finished floor.

Regarding the size of the burners to be chosen, it may be stated in general that for average-sized rooms it is much better to have a few large burners lighted than a larger number of smaller burners.

For lights in hallways, staircases, passages, servants' bedrooms, and the servants' department in the basement, plain, durable fixtures, with little ornamentation, should be chosen; but in the principal rooms of a house, the fixtures should be selected with a due regard to the dimensions of the rooms, the style of decoration, the furniture and the purpose of the room.

The following suggestions may serve as a guide in locating the lights:

Beginning in the *cellar*, there should be a light near the foot of the cellar stairs, also one or several lights in the passages, a light in the wine cellar, and one near the furnace or other house-heating apparatus. Where there is a steam boiler there should be a light near the same with a polished metal reflector, so placed as to throw the light on the water glass tube and on the steam gauge. The side brackets should be plain, stiff brackets, and the burners should be three-foot burners, preferably surrounded with large wire cages.

In the *kitchen* there should be a two-light pendant with three-foot burners over the center-table, the pendant preferably to be hung with a swivel joint, so it can be placed out of the way whenever the table is removed. There should be a swing bracket light at the kitchen range, and in large kitchens another light over the kitchen sink, each of these to have a four- or five-foot burner. If there is a gas range in the kitchen this should have a separate supply pipe, with a three-quarter or one-inch outlet according to the number of gas burners in the gas range.

If there is a separate *servants' sitting room* or *dining hall*, there should be a two-light pendant over the table, with three-foot burners.

In the *laundry* there should be a fixed center light, where the ceiling is high, or a hinged pendant in case of a low ceiling, also one side bracket light at the wash tubs, with a four- or five-foot burner. If the heating of the sadirons is done by gas there should be a separate supply for these. All the lights should be surrounded with well-fastened large wire cages to protect the flame.

In the kitchen *store-room* there should be a single light pendant, the drop light being preferred, because it does not interfere with the shelves.

There should be a bracket light at the *refrigerator*, and one in the *scullery* at the sink.

In the *butler's pantry* a side light over the pantry sink is desirable, in addition to a center light; but as a rule one two-light pendant with three-foot burners is ample. Should there be a gas plate warmer, this should have a separate supply.

Continuing the consideration of the servants' department, there should be one side light, with three-foot burner, and with large wire globe or cage in each *housemaid's closet* or at the housemaid's sink. In the *linen closet* the light should preferably come from a pendant with wire cage.

The *servants' bath-room* should have a side light with three-foot burner, and there should be in each *servants' bedroom* one light, not placed near the bed or near window curtains. These lights should be supported on stiff brackets, and they should be surrounded with wire cages. Three-foot burners will give ample light, and it is particularly desirable, if the servants' bedrooms are on the top floor of the house, where the gas pressure is highest, to use automatic governor burners.

The *servants' stairs* and *rear halls* should have a sufficient number of single stiff bracket lights, with three-foot burner and wire cage. As a rule, one light on each floor landing will be sufficient. The use of a polished reflector to light up dark passages is much to be recommended.

Turning now our attention to the front portion of the main house, there should be a center drop light, with one four- or five-foot burner in the *outer vestibule*, and this light should be so placed as to light up the house number over the front door. Outside lanterns, though not much used except for large mansions, form a very useful feature and are a great protection against burglaries.

There is generally a center light in the *front hall* near the inner vestibule door, or directly opposite the hat rack; also one or more bracket lights in the main hall passageway.

A bracket light, sometimes coming through a mirror, is placed on the upper stair landing, and there are stiff bracket side lights with one or two arms, in the center of each *staircase hall*. Lights on the stair newels are not used as much as in former days.

In the *drawing-room*, *reception-room* or *parlor*, a better, more uniform, and more equally diffused illumination can be obtained by discarding the cumbersome center chandelier, with its cluster of lights all concentrated in one place, and placing instead side lights around the walls. In rooms exceeding eighteen feet in width, however, both side lights and chandeliers should be used. Bracket lights may also be placed at the sides of the fireplace, or upright lamps on the mantelpiece.

The drawing-room, above all rooms in a house, requires a brilliant illumination in order to light up effectively the faces, the dresses and the jewelry of the company, and therefore large, five- or six-foot burners should be used. It should also be borne in mind that the color of the walls and ceiling, of the draperies and furniture, has considerable bearing upon the question of lighting up such rooms properly. Light colors reflect the light, and are, therefore, better than dark colors, which absorb light. Dark-colored rooms require more lights and larger burners to be effectively lighted.

A flood of warm and soft light may be obtained by using sun burners in the ceiling, and this is much to be preferred to the direct glare from ordinary chandeliers. Owing to the difficulty of placing gas lights close up to the ceiling, it must be admitted that for ceiling illumination of drawing-rooms the electric light offers a more promising field to the artist. The electric glow lamp is also much to be preferred from a decorative point of view for lighting up cosy corners, recesses in bay windows, etc.

Regarding the lighting of *dining-rooms*, however individual tastes may differ, the chief problem is, without question, to light up the dining table brightly and artistically, yet not too brilliantly. A center chandelier, with four, six or eight arms, and five-foot burners, should be the chief feature, to which is sometimes added an extension or slide pendant with Argand burner. There should be side lights at or on the sideboard, and sometimes side lights at the mantelpiece. Where there are fine paintings on the wall, side lights should be suitably arranged so as to display these to best advantage. A side light at the carving table may also prove a great convenience.

As the dinner table is the chief feature of the dining-rooms, so are the reading table and the writing desk the chief features of the *library* and the *sitting-room*. Where there is a fixed center-table a chandelier with extension lamp may be used, together with side lights at the reading table or reading chair. The light in this room should not be too brilliant, except at the writing desk or the reading table, where an Argand table lamp, or a bracket Argand burner of good candle-power should be fitted up so as to concentrate the light.

In all these rooms grate fires or gas logs may be fitted in the fireplaces and require separate and independent supply lines from those gas pipes which supply the fixtures for lighting.

The *billiard-room* requires a drop in center of the billiard table, with from four to six large burners; also a side light at the lavatory.

The *boudoir* of the lady of the house, and the *den* of the master of the house may be treated differently in each case according to the taste of the occupant, and side illumination will generally be used, together with a strong and powerful light at the reading desk or writing table.

The *sewing-room* should have a strong side bracket light at the sewing machine, with a five-foot burner.

Bedrooms, as a rule, should not have ceiling lights. There should be a bracket light at the wall against which the bed stands, near the bedstead, and another light near the washstand. The toilet table or bureau generally has two side lights, one on each side of the looking glass, to which, for ladies' dressing tables, a mirror light, suspended high or dropped from the ceiling in center and in front of the bureau, is added. Near the fireplace there may be a bracket light for a reading lamp, and if there are gas logs there should be for these a separate supply.

According to its size and the number of fixtures, the *bath-room* may have one or two stiff side lights with four- or five-foot burners, generally one light at the wash basin and another at the water closet. There should be a separate gas supply for a gas heating stove or a gas fireplace heater, or for gas jets in local ventilating flues. The *nursery* may be lighted similar to the bedroom.

The hints thrown out in the foregoing paragraphs may be used as a general guide in locating the gas outlets of a house. As regards the large rooms, no hard and fast rules can be given, as so much depends upon the individual taste of the decorative artist, and upon the decorative features of the house.

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from Vol. cxxxvii, p. 468.*]

Steam.—Such works as those already referred to have, in many cases, been carried out by the Government at public expense, and hence they have often been classed as public works, although some of them, especially railroads, are, in this country, private enterprises. It is in connection with such works as these that the common idea of engineering has been exclusively or, at least, chiefly associated. In former times works of great magnitude were almost always undertaken by the Government, because it alone could command the needful capital to execute them ; or if in any case private capital was invested, it was subsidized by the Government. Works for the Government at the present day are often let out in whole or in part to private parties to execute. Moreover, this is preëminently an industrial age, and we have consequently so much engineering involved in the operations of private concerns that the total amount done for them far exceeds that done for the Government. Hence we shall, later on, consider what may be termed private enterprises. With the exception of mining and a few others, we might include most all such enterprises as involve engineering to a considerable extent under the term manufacturing.

Before entering upon a consideration of what are the engineering problems involved in these industries, I must first refer briefly to the development of the use of steam and the steam engine. To-day one can hardly undertake any engineering work, even of small magnitude, without the use of steam, and no engineering work of any considerable magnitude can be carried on without a considerable use of steam. We have become so accustomed to this state of things that it is very hard to realize the condition of the industrial world before the general introduction of this agent, when the only available sources of power were water-power, wind-power and the muscular power of animals and men; and when we contemplate any large work of those days we are led, in expressing our admiration, to couple our words of praise with the remark, "notwithstanding their lack of facilities for performing such work." I shall not stop to consider the earliest history of the introduction of steam for power, involving the work of Hero, of Savery, of Newcomen and of others, but I cannot avoid making some mention of James Watt, for, if we enumerate the important problems that have arisen affecting the development of the steam engine from the beginning down to our own day, we shall find that almost all of them were recognized and taken into consideration in some form by Watt; and, although the improvements that have since been made are enormous, and although the economy of steam that can be realized to-day is far greater than that obtained by Watt, nevertheless the contrast between the modern engines and those of Watt, enormous as it is, is not as great as that between Watt's engines and those of his predecessors, and, moreover, one great reason for the success of James Watt lay in the thoroughly scientific manner in which he did his work. Instead of attempting to evolve out of his own mind, without investigation, a successful engine, he began by making a long and careful series of experiments by means of such an engine as was then available, and by means of other apparatus which he made for his special purposes, and, by studying the faults, the shortcomings, and the chances for improvement in the then existing state of steam engine practice, he succeeded in working out the means of remedying to a very considerable extent the difficulties encountered. He made a series of experiments to determine the actual amount of coal and water consumption per horse-power per hour in the Newcomen engines, such as were then in use in the mines for pumping water. He found the amount of coal and water consumed to be very excessive, so considerable indeed that the cost of using such an engine was often prohibitive.

He began experimenting with the model of a Newcomen engine to which he had access, and found that the boiler was too small to furnish the requisite steam for the engine. He made a new and larger boiler, and then proceeded so to arrange the apparatus that he could determine, by actual weighing, the amount of water evaporated, and the amount of steam used by the engine in any given time.

In the Newcomen engine, steam was admitted under the piston, and thus the piston was raised; then, for the purpose of allowing the piston to descend, the steam was caused to condense, either by cooling the cylinder by water poured on the outside, or else by a jet of water introduced into the cylinder. In either case the loss was very considerable, and before he completed his experiments he came to the conclusion that in the Newcomen engine at least three-fourths of the steam was wasted, and he set about trying to get rid of this loss.

He gives, as the results of his researches:

(1) The capacities for heat, of iron, copper, and of some sorts of wood, as compared with water.

(2) The volume of steam as compared with that of water.

(3) The quantity of water evaporated in a certain boiler by one pound of coal.

(4) The elasticities of steam, at various temperatures greater than that of boiling water, and an approximation to the law which it follows at other temperatures.

(5) How much water in the form of steam was required at every stroke by a small Newcomen engine, with a wooden cylinder 6 inches in diameter and 12 inches stroke.

(6) The quantity of cold water required in every stroke to condense the steam in that cylinder, so as to give it a working power of about seven pounds on the square inch. These researches showed him what were the difficulties, and cleared the way for his improvements. His first means of saving steam was by the use of an independent condenser, and an air pump, instead of condensing the steam

in the cylinder itself. The following description of his inventions up to 1769 is given in his patent:

"My method of lessening the consumption of steam, and consequently fuel in fire engines, consists in the following principles:

"(1) That the vessel in which the powers of steam are to be employed to work the engine, which is called 'the cylinder' in common fire engines, and which I call 'the steam vessel,' must, during the whole time that the engine is at work, be kept as hot as the steam which enters it—first, by inclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam or other heated bodies; and thirdly, by suffering neither water nor other substances colder than the steam to enter or touch it during that time.

"(2) In engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam vessel or cylinder, though occasionally communicating with them. (These vessels I call condensers, and while the engines are working, these condensers ought at least to be kept as cold as the air in the neighborhood of the engines, by application of water or other cold bodies.)

"(3) Whatever air or other elastic vapor is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam vessels, or condensers, by means of pumps wrought by the engines themselves, or otherwise.

"(4) I intend, in many cases, to employ the expansive force of steam to press on the pistons, or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air after it has done its office.

"Lastly, instead of using water to render the piston or other parts of the engine air- or steam-tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver and other metals in their fluid state."

Later, Watt patented the expansion of steam and six methods of using it; the double-acting engine; the double or coupled steam engine; the use of a rack on the piston rod, working in a sector on the end of the beam to secure a truly rectangular motion; a rotary engine. He next decided to add a fly-wheel to his engines to equalize the effect at different parts of the stroke. He then devised his parallel motion; also the arrangement of cross-head and guides now universally used. He also patented the poppet-valve; also a revolution counter; the pendulum governor and mercury steam-gauge; the water glass and the steam engine indicator.

The above gives a partial list of the devices and improvements introduced by Watt into the steam engine; and, whereas we should to-day much prefer to have a modern engine rather than an engine of that day, nevertheless, it is plain that the rate of development is not at all as great as that which represents the change from the engine of Newcomen to that of Watt. That the introduction of the Watt engine to pump water from mines, and to run mills and shops, made a complete revolution in the ways of carrying on industrial pursuits is evident, and equally so that to the work of Watt is due the development of the steamboat and of the locomotive. Indeed, it was one of Boulton & Watt's engines that Fulton placed in the *Clermont*, to drive it when he made his memorable first voyage up the Hudson, in 1807.

Whether, therefore, we consider railroads, or navigation, or mining, or manufacturing of any kind, or applications of electricity, we find that the steam engine has revolutionized the industry, and that no one to-day can undertake engineering work of any magnitude without having to make use of steam.

Now, without stopping to consider further what was the work of the early days—of Watt, of Fulton, of Stephenson, and of the host of other men who had a part in introducing and developing the steam engine—let us consider what have been the later developments that have been made in its use.

And here we may say that the entire impetus towards an investigation of the defects of the steam engine and the remedies therefor, has been the desire to save coal, and hence to cause the engine to do its work, and to make the boiler produce the necessary steam, with a smaller coal consumption. Economy of coal became at once an item of the greatest importance in the case of the marine engine, for every ton of coal less not only saved the expense of the coal, but also space in the vessel for carrying cargo, which was profitable freight. Indeed, in the early days of the marine engine, one of the questions raised touching its practicability was whether it was possible to carry enough coal for a long voyage. Hence it is that we find on the whole that improvements and economy were more sought after in the case of the marine than in the case of either the stationary or the locomotive engine.

Another fact that has aided in making the improvement of the marine engine more rapid than that of either of the others, is that the work done by it is more nearly constant; and, besides this, when the boat is on a long voyage the engine runs night and day, so that the fires are not put out each day, and rekindled as often.

Next to the marine engine, in this regard, stands the stationary engine, and especially the large pumping engine; although, in the case of the small pumping engine, economy of steam and hence of coal is usually sacrificed to cheapness of first cost and ease of repairs.

Why more attention has been paid, until lately, to economy of steam in the case of the large pumping engine than in the case of other stationary engines may seem strange. but the reason is probably to be found in the fact that such engines are necessarily owned either by the Government or by some rich corporation, whereas it has only been with the enormous development of manufactures that belongs preëminently to more modern times that large engines have been required to any great extent in manufactories, and even to-day we often find in use, in a large manufactory, a number of small engines in many cases in which the substitution of one large one would make a decided saving of coal.

In the earlier engines the valves were set to cut off at some definite point, and the steam supply was automatically adapted to the load on the engine by means of a throttle governor, which varied the pressure of the steam when it came into the cylinder. The first attempt to do away with the losses consequent upon the throttling of the steam was made by George H. Corliss, of Providence, who caused his governor to regulate the point at which the steam should be cut off, and, therefore, he left its pressure as it came into the cylinder undisturbed.

Though this is not one of the earliest improvements, it is, nevertheless, one that has been very far-reaching in its effects, and it is rare to-day that we find any large engines that throttle their steam, as large engines are almost invariably provided with an automatic cut-off.

Indeed, the influence that Corliss exercised on stationary engine practice was very great, and, throughout Europe and America, we find that the Corliss type of engine is very extensively used. But while much may be said in favor of the rotary valves and the drop cut-off, which are so characteristic of the Corliss style of engine, Mr. Corliss, nevertheless, was not identified to any extent with the modern compound and triple engines.

The saving that could be obtained by using steam expansively, instead of allowing it to follow the piston throughout the stroke, was recognized by Watt, and this feature is to be found among the early engines, and so deeply were engineers impressed with it, that they began to build engines to run with shorter and shorter cut-offs, expecting to save steam thereby; but, later, attention was called by a number of engineers and others to the fact that cylinder condensation was an important item to consider, and that with very short cut-offs the effect of cylinder condensation was to bring about a waste of steam; so that, for every different engine running under definite conditions as to steam pressure, back pressure, etc., there is a certain cut-off which produces a greater economy of steam than either a longer or a shorter one.

To explain to any one not familiar with these matters what is meant by cylinder condensation, I will say that the steam, when it enters the cylinder, is very hot; thus, steam of 100 pounds (*i. e.*, 114·7 absolute) pressure, has a temperature of 337°·7, and, when it leaves, it has a low temperature; thus, if it escapes into the air, its temperature is 212°, or if it escapes into a condenser it is even less.

Now, during a given stroke, the steam on one side of the piston has been escaping into the air or into a condenser, and the metallic walls of the cylinder have been exposed throughout this stroke to this low temperature, hence they must have cooled off considerably and be very much colder than the steam which enters immediately afterwards, at the beginning of the return stroke.

When the steam enters at a high temperature and comes in contact with the cold metallic walls, its first function is to condense and heat these walls, and hence a large amount of steam is condensed in heating up the walls of the cylinder instead of performing work. Now, this cylinder condensation, as it is called, is greater, the greater the difference between the temperature of the steam when it escapes into the air or into the condenser, and that of the incoming steam, and anything that can be done to decrease that difference will decrease the loss due to cylinder condensation. If the cut-off is made shorter and shorter, the gain due to using steam expansively is soon offset by the greater loss due to cylinder condensation.

It is the consideration of the losses due to cylinder condensation that has, perhaps, more than almost anything else, brought about the more recent improvements in the steam engine, both marine and stationary, and now it is also beginning to have its effect in the case of the locomotive. There are several who claim to be entitled to the credit of first pointing out the fact that cylinder condensation exists, and it is not long since a number of articles appeared in the scientific papers claiming the credit respectively for Isherwood, for D. K. Clark, and for Hirn. It is not of any special interest to us to settle this question.

As to the fact that cylinder condensation exists, James Watt found that the chief source of loss in the Newcomen engine was cylinder condensation, and that was the first thing he undertook to remedy, thereby saving as much as three-fourths of the steam used by Newcomen's engine.

The thing of real importance for us, is to have a number of well-arranged and careful scientific experimental investigations to determine its amount under a variety of different conditions, so fully as to give us reliable information as to how to reduce it to a minimum.

Now, neither of the men mentioned above has made any such complete series of experiments, nor has any other one man done it, but it is a matter in regard to which, through the exertions of a great many, we are making decided progress, and the chief set-back is due to the attempts and claims of those who, ignoring the good example of Watt, make experiments in an unscientific or careless way, and put forward as true, conclusions that are not, and which, if accepted as facts, lead to costly experiments and certain failures. Nevertheless, a good deal of progress has been made, and the world is very much alive to this question to-day. The result has been the adoption long ago of the compound marine engine, and of late of the triple expansion marine engine, so that we find on almost any large steamer either a compound or a triple engine.

In stationary engine practice, the compound engine has frequently been used for water-works engines, but it is only in later years that it and the triple expansion engine have been introduced to any great extent into mills and manufacturing establishments in the United States; and it is only very recently that the compound principle is being introduced into locomotives. A compound engine is one in which the steam performs only a portion of its expansion in one cylinder, and then it enters another and a larger cylinder at a lower pressure, and completes its expansion therein. The result is that the difference of temperature in each cylinder between the entering and the departing steam is less than it is when the expansion is completed in a single cylinder, and therefore the cylinder condensation is less. In the case of a triple expansion engine the expansion is only completed in three cylinders, the steam doing work in the first, then entering the second at a lower pressure and expanding therein, then entering the third at a still lower pressure, in which last the expansion is completed.

The one reason for expanding in more than one cylinder is to diminish cylinder condensation, while taking advantage of the expansive force of the steam.

Now, in regard to the progress being made in the matter of economy in engine construction, some of the questions that naturally arise are, in any given case:

(1) What degree of expansion should be used?

(2) Is it best to use, under the conditions in hand, a non-condensing, a condensing, a compound, a triple expansion, or a quadruple expansion engine?

(3) If a multiple expansion engine is decided upon, what should be the proportions between the different cylinders?

(4) Should receivers be used, and of what capacity?

(5) To what extent and in what way should steam jacketing be carried out?

(6) What effect, if any, has the piston speed, or the rotative speed on the economy of steam?

(7) Is it better in any given case to adopt a jet, or a surface condenser?

(8) What kind of boilers should be used, and what should be their proportions?

All the above are questions which concern the economy of coal and water; but there are of course many other questions to be answered and conditions to be considered; such as—

(9) What degree of regularity is it necessary to maintain, and how shall we build the governor and the fly-wheel to attain it?

(10) All parts bearing loads must be made of the requisite strength, and the stresses should be carefully calculated so as to secure safety.

As an instance of carelessness in this regard, I need only call attention to the fact that every now and then we hear of some fly-wheel that has burst, has killed a number of people, and destroyed a great deal of property, and I will say that I have found a number of wheels where it is evident that the stresses were not properly calculated by the designers, and where there is a very small factor of safety, and consequently a large element of risk, and I do not doubt that a proper care in the design would avert a number of the accidents that occur.

Another instance where the better class of builders do take at least a fair amount of precaution as a rule, but where, in many cases, great risks have been taken, is in the case of steam boilers, though the accidents due to steam boiler explosions are attended with so much danger that more effort has been made to exercise a proper supervision in their construction. Indeed, the steam boiler insurance companies exercise a considerable check on the existence of dangerous boilers.

Reverting to the questions concerning the economy of coal and water, a great deal more is known to-day than formerly, and the increase of knowledge on the subject has operated in causing material improvements in engines, particularly for large plants; nevertheless, the complete answers are to be determined in the light of careful and scientific experiments, and these questions now are no longer to be decided by rule of thumb, nor by haphazard trial. They are no longer questions for the inventor to solve, but require the best efforts of the engineer. The really scientific work on this subject is of very recent date, but those who take the responsibility for the expenditure of large amounts of money for steam plants are ever on the alert to get the benefit of any such experiments.

In considering the second question, for instance, the decision must depend upon what other use, if any, is to be made of steam.

Thus, if a very large amount of steam of a very low pressure is required, it may be that it will be more economical to use a simple non-condensing engine in certain cases, rather than a compound, and then to utilize the exhaust steam for the other purposes, as, for instance, for heating; for the exhaust steam is practically as efficient for heating as live steam, and hence, in cases where all the exhaust steam is used for heating, if we estimate the expense of our power, in coal, at five per cent. of what it would cost if the exhaust steam were not used, we shall have made a large estimate.

Some attempts are now being made to use stationary compound engines with not very high initial pressures, exhausting into the air, or against a small back pressure, and considerable economy is claimed for them. They are now in the experimental stage, however, and it is too early to give a very positive decision in any cases that have thus far been developed. Nevertheless, in locomotive practice, the case is precisely one where the exhaust from the low-pressure cylinder takes place into the air, but in this case the initial pressures are very high, and while the experiments that have been made have not been as full nor as accurate as could be wished, enough has been done to show that a decided saving of coal can be obtained in many cases by the use of the compound locomotive when properly designed and operated.

Another matter that requires the careful consideration of the engineer is how to transmit the power from the engine to the different places where it is to be used, and to see that all this is properly designed. This, in some cases, is accomplished by gearing, in some cases by belting, and in many cases by ropes running in grooved pulleys.

Now that electricity is coming to play such an important part in all our engineering operations, I do not doubt that there will soon be cases where the engine will be employed in driving one or more dynamos, using up a part or the whole of its power, and then the power will be transmitted to the different points where it is needed, as the different floors, or the different shops, or to the different groups of machines, and sometimes perhaps to the different machines themselves by a wire from the dynamo, connected at the other end with an electric motor.

There is no doubt that a large engine can be run with much greater economy of coal than several smaller ones delivering in all the same amount of power; hence it is desirable, whenever there are not other reasons which offset it, to concentrate the power plant in one place, and in cases where this is not possible, to do as much as can be done towards concentration. In many cases it cannot be carried out, and in others it can only be done partially; nevertheless, if the power is transmitted by electricity this will be an aid towards such constructions.

Next comes the question of boilers. The contrast between the boilers used at or about the time of Watt and those used to-day is very marked. The pressures in use were very low, and boilers could be made of most any material and of most any shape. Copper was a favorite material, and Watt, in some of his experiments, even tried wood. Later on, cast iron came into use, and later still, wrought iron and now steel has almost displaced wrought iron in boiler construction. Of course, cast iron is still used in many sectional boilers, and in some of the complicated fittings of cylindrical boilers. The early boilers were made without any special pains being taken to calculate their strength, and the pressures were increased by those who used them with so much carelessness that there were a great many accidents.

As pressures rose, however, it became more necessary to look after the matter of strength carefully, and this fact began to have its influence in the shapes and designs of boilers. But even when pressures had reached thirty or forty pounds per square inch, there were still in use a great many marine boilers having a number of flat surfaces which, of course, had to be stayed, but now the pressures have increased to as much as 150 and even 200 pounds, and it has been necessary to adopt the cylindrical form for the marine boiler, so that the marine boiler has changed enormously since early days.

Of the different types of stationary boilers there is no end, but all of them are very different from the boilers of early days. Moreover, pains are taken to day to avoid loss of heat; thus economizers are frequently introduced, by which the feed-water is heated by a portion of the waste heat which would otherwise be lost by going up the stack; pains are taken to lag the boiler if it is internally fired, or to make some provision in any case to prevent the escape of heat; the pipes are covered, and precautions are taken to save heat in every possible way. Also, the feed-water is very commonly heated by exhaust steam, or otherwise. Then, in establishing a power plant the chimney demands consideration. It must be adequate for the boilers, and it must be properly constructed.

Provision must be made for receiving and storing coal, and this should be arranged so as to save labor, as far as possible, and to deliver the coal as near the boiler as is feasible.

Another use of steam which presents itself is the heating of buildings, and this has to be done in many places where no power is needed and no engine is run, except a pump to feed the boiler, and perhaps an elevator may be run by power derived from a small engine or pump. In this case there used to be but one way of effecting the heating, viz.: to place radiators in the rooms to be heated, and to convey steam to these radiators by pipes. Now, however, ventilation is considered an important factor, and systems of heating are adopted which provide for ventilation at the same time.

I will explain one of these systems as exemplified by what is done in the Engineering building of the Institute of Technology. Steam is used in the building for heating and for power; it enters through the main pipe and passes through a separator before continuing on to the engine; water and wet steam are drawn from the bottom of the separator and put into the heating system, and so is also the exhaust steam from the engine, when the latter is not condensed in the condenser. Besides this, live steam is used whenever there is not enough of the other. The steam passes into the various coils, which will be described. There is, in front of an opening in the wall, the main coil, and in front of that a fan run by a special small engine. This fan draws air in through the coil, *i. e.*, around the pipes forming the coil, and thus the air becomes heated. Then the air is driven by the fan into a duct, which extends all around the sides of the basement into which it is delivered in a slightly compressed state. This duct is connected with a number of upright channels leading to the various rooms of the building, all of them being lined with tin. At the base of each of these vertical ducts is an auxiliary radiator, to which steam is admitted, so as to add more heat to the air, in addition to that which it received from the main coil. Then there are registers in the uprights which open into the different rooms, also other registers which connect the rooms with outlet flues. Thus, the rooms are heated by the warm air introduced into them. Moreover, there are a number of direct radiators in addition, to provide for more heat in very cold weather. There is also an arrangement for automatically regulating the temperature, so arranged that when it rises or falls a certain amount, 1° above or below the normal, an electrical connection is established, which causes compressed air in a small pipe to close or open the steam valves of the direct radiators or the registers in the case of the indirect system.

There are many other methods of using steam for heating, to which there is not time to refer. Neither is there time to dwell further upon the almost countless uses for steam in connection with the industries and with the civilization of the world.

[*To be continued.*]

THE HEATING AND VENTILATION OF LARGE BUILDINGS.

BY ALFRED R. WOLFF, M.E.*

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

The large building of the present day, at least in America, must meet the needs and comforts of an intense, concentrated, nervous and busy "indoor" community—the product of our "rush" civilization. The very fact that both business and pleasures are indulged in on a large scale, in ceaseless haste and at high pitch, renders the community participating in them all the more sensitive to external discomforts, and unwilling to put up with any not of their own individual creation. The very "crowding," and the physical strain and nervous excitement incident thereto, render it important in the battle of existence called "life," that the best conditions of health be artificially secured, so as to counteract, if possible, the individual natural neglect. But aside from this, and from a loftier point of view, the modern tendency is to demand the best attainable in every department of work. Whatever the reasons, the demand exists that the best conditions of health and comfort be secured in the large buildings, the meeting places of the multitude. Thus there must be equable temperature, pure air, excellent light and fine sanitation, obtained artificially, almost irrespective of the control, crowding, physical and nervous state of the inmates of the building, and irrespective of climatic and other conditions external to the building.

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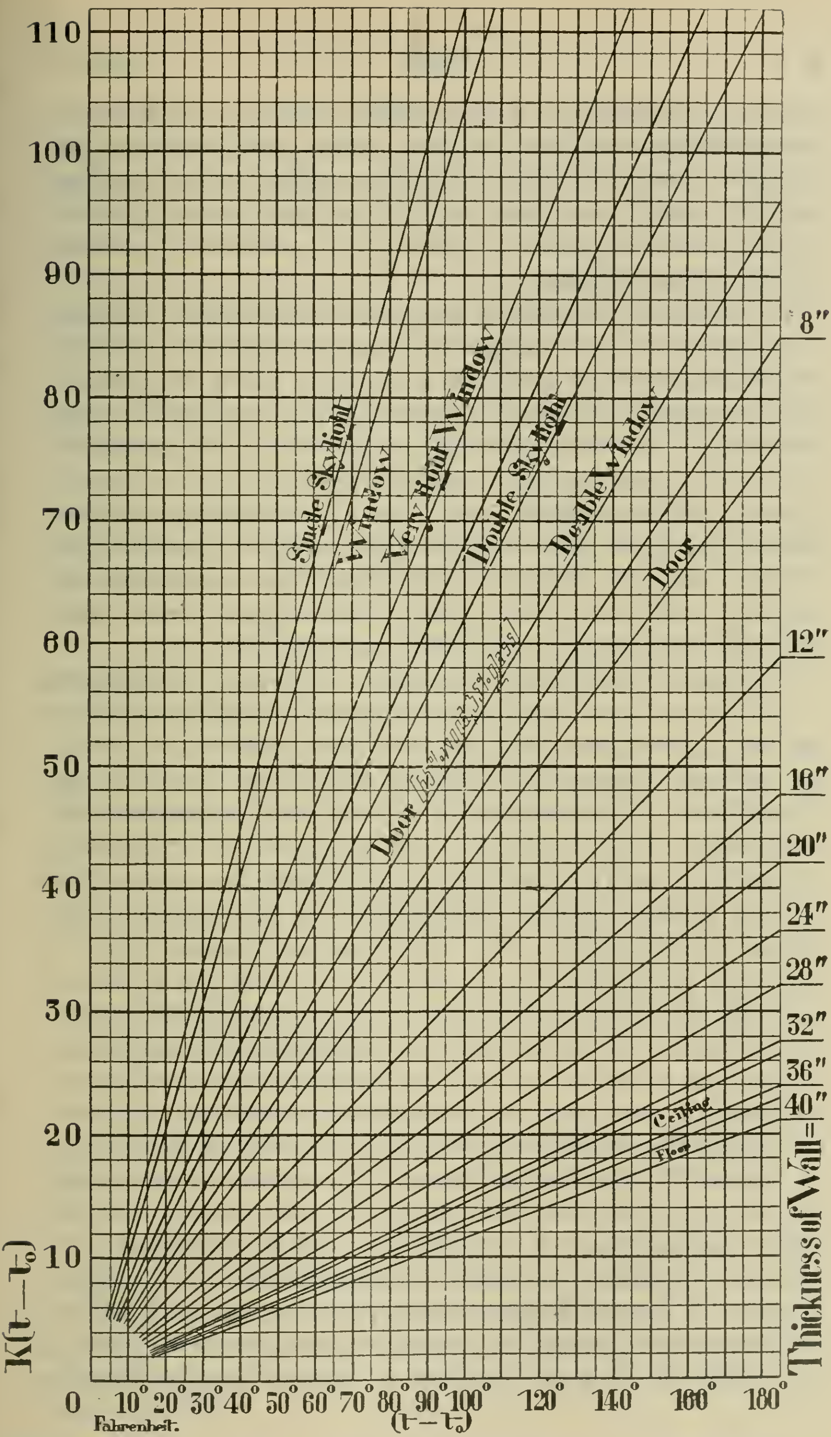
* A Lecture delivered before the Franklin Institute.

It is the solution of this problem which converts no small portion of the large modern building into a great factory for the generation and distribution of light, heat, cold, and currents of air and water. It is no longer unusual for our large hotels, office buildings and auditoriums, to contain a boiler plant of 1,000 horse-power, with a corresponding electric lighting, heating, cooling and refrigerating system, nor for the equipment of these plants to require an outlay of hundreds of thousands of dollars. And with these large machinery interests at stake, it becomes important that the skill of the trained engineer be called into play to ensure, in co-operation with the architect, the most desirable and best attainable results, with a judicious expenditure of money.

During the past few years it has been my good fortune to have acted as consulting engineer in the design and erection of the engineering equipment of a number of large buildings, and, more particularly, of the heating and ventilating plants. On this account, doubtless, your otherwise



Heat transmitted, in British thermal units, per square foot of surface, per hour.

astute committee has been deluded into the belief that a few words from me in relation to some of the principles and problems entering this specialty might be of passing interest; and if you thus become the innocent sufferers I, at least, am the gainer by having the pleasure of meeting you here this evening.

A systematic account of the various methods of heating in vogue and their comparative merits, would, on account of the time-limits of our talk, necessarily savor too much of the elementary text-book, and would also, in all probability, convey but few facts not already known to you, or readily secured by perusing any standard work on the subject of heating and ventilation. So I have concluded to be real unsystematic, to make no attempt to be exhaustive, and only to relate at random a few points in connection with heating and ventilating large buildings, which have appeared of interest to me in my own practice.

I present, herewith, a diagram, showing, for different classes of surfaces composing buildings, coefficients (K) of transmission of heat per hour for each square foot of surface for various Fahrenheit degrees differences between the temperature of the interior of a room and its external surroundings. This diagram is the graphical interpretation, in American units, of the practice and coefficients prescribed by law by the German Government in the design of the heating plants of its public buildings, and generally used in Germany for all buildings. During the past six months, I have checked these coefficients by examples of good American practice, and have found so satisfactory an agreement that it has convinced me of the soundness of the German coefficients, and their applicability to American practice; if, indeed, the well-known care and authority of publication of applied science under German Government patronage did not itself bespeak confidence. In the formula for total heat transmission, $Q = S K (t - t_0)$, K represents, for various materials composing buildings, the loss by transmission, in British thermal units per hour, for each degree of difference between the temperatures on the two sides of the material; S is the amount of transmitting surface in square feet; t is the temperature in Fahrenheit degrees at the interior side; and t_0 the temperature in Fahrenheit degrees at the exterior side of the surface. The value of K varies, of course, not only with the class of surface, but also with its thickness. If, by means of the coefficients given below, and summarized in multiples of temperature differences in the diagram, the loss by transmission of heat to the outside is calculated, we obtain the heat to be conveyed to the room in order to make good the loss due to transmission. This does not, of course, cover the additional heat to be conveyed on account of change of air for purposes of ventilation, but merely represents the loss due to heat transmission through walls, ceilings, windows, floors, etc., of buildings of ordinary good construction, with such slight accidental or natural ventilation as results from the porosity of the materials and construction.

In detail, we have the coefficient of transmission K as above defined, and as prescribed by the German government (transformed into American units):

FOR EACH SQUARE FOOT OF BRICK WALL OF THICKNESS:

Thickness of brick wall =	4″	8″	12″	16″	20″	24″	28″	32″	36″	40″
K =	0·68	0·46	0·32	0·26	0·23	0·20	0·174	0·15	0·129	0·115

1 square foot, wooden beam construction, planked over or ceiled: . as flooring, $K = 0{\cdot}083$
. as ceiling, $K = 0{\cdot}104$
1 square foot, fireproof construction, floored over: . . . as flooring, $K = 0{\cdot}124$
. . . as ceiling, $K = 0{\cdot}145$
1 square foot, single window, ... $K = 0{\cdot}776$
1 square foot, single skylight, ... $K = 1{\cdot}118$
1 square foot, double window, ... $K = 0{\cdot}518$
1 square foot, double skylight, ... $K = 0{\cdot}621$
1 square foot, door, ... $K = 0{\cdot}414$

These coefficients are to be increased respectively, as follows:

Ten per cent. where the exposure is a northerly one and winds are to be counted on as important factors.

Ten per cent. when the building is heated during the daytime only, and the location of the building is not an exposed one.

Thirty per cent. when the building is heated during the daytime only, and the location of the building is exposed.

Fifty per cent. when the building is heated during the winter months intermittently, with long intervals (say days or weeks) of non-heating.

The philosophy of these increases is, of course, apparent; for the coefficients, as given, are for heat transmission alone, in usual every-day practice, where the temperature differences in the transmitting portions have assumed a fixed relation with a corresponding fixed rate of flow of heat. But if the building gets chilled or entirely cold, through days or nights of disuse of heating system, the exposed heat-transmitting portions must be first warmed to the staple degree referred to, which demands for the time being additional heat beyond the ordinary rate of supply, if the period of warming up shall not be excessive. So, too, special cold winds beating on the exposed surfaces form additional heat-abstracting media, besides increasing the amount of cold air entering the building through the pores of the materials, and through the ordinary cracks and crevices of well-constructed buildings.

In connection with calculations for heat transmission by means of the coefficients here presented, the German government prescribes that computations be made on the basis of the following assumed lowest temperatures:

External temperature,		4° F.
Assumed lowest temperature of non-heated cellar and other portions of building permanently non-heated,		32° F.
Vestibules, corridors, etc , non-heated, and at frequent intervals in direct contact with external air,		23° F.
Air spaces between roof and ceiling of rooms,	Metal and slate roofs,	14° F.
	Denser methods of roofing, such as brick, concrete, etc.,	23°F.

As the temperature to be attained in rooms of various kinds, the German government prescribes for:

Stores and dwellings,	68° F.
Halls, auditoriums, etc.,	64° F.
Corridors, staircase halls, etc.,	54° F.
Prisons, occupied day and night,	64° F.

[*To be concluded.*]

CHEMICAL NOTES.*

By Jos. W. Richards, Ph.D.

Specific Gravity of some Fused Salts.—In the production of aluminium, as at present carried out, calcined alumina is dissolved in a bath of fused cryolite, or fused cryolite plus aluminium fluoride, and an electric current passed through from carbon electrodes. Whatever are the reactions which take place whereby the aluminium is liberated, the final result is simply the liberation of aluminium at one pole and oxygen at the other, as long as the bath is kept supplied with all the alumina it can dissolve. The following train of thought suggested itself to the writer: If the specific gravity of aluminium is 2·7, and that of cryolite 3·, how is it that molten cryolite floats on top of molten aluminium?

In order to get the specific gravity of the fused materials, a tight iron mould was taken and carefully measured. It was then filled level with the different molten salts, and from the weight of the salt and the computed volume of the mould, the specific gravity was calculated.

The following results were obtained:

	Specific Gravity.	
	Molten.	*Cold after Fusion.*
Commercial aluminium,	2·54	2·66
Commercial cryolite from Greenland,	2·08	2·92
Cryolite which contains all the alumina it can dissolve,	2·35	2·90
Cryolite + aluminium fluoride added in such quantity as to make a salt of the formula Al_2F_6. 2NaF,	1·97	2·96
Same as above, but containing all the alumina it can dissolve,	2·14	2·98

It can, therefore, be seen that while aluminium itself expands comparatively little in melting, the salts from which it is made expand from one-fifth to nearly one-third of their volume, and, therefore, while heavier than aluminium when cold, they are lighter than aluminium when molten.

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* Presented at the meeting of the Chemical Section, held April 17, 1894.

An Instructive Case in Thermo-Chemistry.—The writer endeavored to decompose a solution of ferrous sulphate by boiling it with finely-ground calcium carbonate, thinking that the following reaction might take place, precipitating the iron:

$$FeSO_4 + CaCO_3 = FeO + CaSO_4 + CO_2$$

The boiling was continued an hour, without a trace of ferrous oxide being precipitated.

The experiment was repeated with magnesium carbonate, thinking that the solubility of the magnesium sulphate might assist the reaction. The result, however, was similar to the first.

Thinking that possibly the decomposition would take place if the carbonic acid were first driven from the reagent by heat, the experiments were repeated with milk of lime and milk of magnesia. The precipitation of the iron was at once evident, showing that the expectation was correct.

Casting up the thermal data of the reactions involved, the figures show exactly why the reactions failed in the first instance and succeeded in the second.

$$FeSO_4.Aq + CaCO_3 = FeO.Aq + CaSO_4 + CO_2$$

Heats of formation, . . . $\underbrace{\underbrace{235{,}600 \quad 270{,}410}_{506{,}010} \quad \underbrace{68{,}280 \quad 320{,}040 \quad 96{,}960}_{485{,}280}}$

Deficiency, ... 21,730 calories.

$$FeSO_4.Aq + MgCO_3 = FeO.Aq + MgSO_4.Aq + CO_2$$

Heats of formation, . . . $\underbrace{\underbrace{235{,}600 \quad 267{,}600}_{503{,}200} \quad \underbrace{68{,}280 \quad 322{,}580 \quad 96{,}960}_{487{,}820}}$

Deficiency, ... 15,380 calories.

$$FeSO_4.Aq + CaO.Aq = FeO.Aq + CaSO_4$$

Heats of formation, ... $\underbrace{\underbrace{235{,}600 \quad 149{,}460}_{385{,}060} \quad \underbrace{68{,}280 \quad 320{,}040}_{388{,}320}}$

Excess, ... 3,260 calories.

$$FeSO_4.Aq + MgO.Aq = FeO.Aq + MgSO_4.Aq$$

$$\text{Heats of formation, } \ldots\ldots\ \underbrace{\underbrace{235{,}600 \quad 148{,}690}_{384{,}560} \quad \underbrace{68{,}280 \quad 322{,}580}_{390{,}860}}$$

Excess, ... 6,300 calories.

To find out why one has failed, and to predict where one may succeed, might be more frequently the office of thermochemistry, if better understood and more frequently applied.

Anthracite Coal in Bucks County, Pa.—The writer found, in 1892, a thin seam of anthracite coal at Hartmann's iron ore mine, one and one-half miles south of Hellertown, on the Springtown Road. The Saucon Valley, in which this mine lies, is a limestone pocket, surrounded by the syenitic ridges of the South Mountain, which have a general trend of southwest to northeast. The mine occurs at the junction of the limestone and granite, at the foot of one of these ridges. The ore is argillaceous siderite. The coal is found in a seam about one-eighth to one-quarter of an inch in thickness, overlying the iron ore and embedded in brown clay, which is somewhat indurated near to the coal. At the point where the specimens were dug out, the coal was within a few feet of the surface. Every indication pointed to it being a true occurrence, found *in situ*, as the clay bank out of which it was dug had apparently never been disturbed. The coal is true anthracite, burning before the blowpipe without any yellow flame to a reddish-brown ash.

LEHIGH UNIVERSITY,
BETHLEHEM, PA., April 17, 1894.

ON THE ANALYSIS OF AMERICAN REFINED COPPER.*

BY HARRY F. KELLER, PH.D.

It is generally conceded that the presence even of minute quantities of other elements in metallic copper has a marked influence upon its physical properties, and especially upon its electric conductivity.

The copper produced in the Lake Superior region is relatively free from injurious admixtures, and is therefore generally preferred when a high conductivity is desired. "Lake" copper is always quoted a trifle higher than the metal from other localities.

Of late years the production of copper from impure sulphide ores has grown enormously, and, at the same time, the quality of the product has steadily improved. It has, indeed, become possible through the introduction of the Manhés converter and the electrolytic process of refining, to obtain from matte a metal nearly, if not quite, as pure as the native of Lake Superior. Unfortunately, it appears that the very slight traces of the impurities retained in it affect the conductivity to a greater extent than is the case in the best lake copper. Silver and iron are the chief impurities of the latter, while electrolytic copper not infrequently contains small quantities of bismuth, antimony, arsenic, selenium and tellurium.

That the exact manner in which these elements affect the physical properties of copper is not better understood, is undoubtedly owing to the lack of rapid, and at the same time, accurate, methods of ascertaining their relative amounts. It is astonishing to note that the works on quantitative analysis published in the English language entirely neglect copper analysis. To my knowledge the important contributions to this subject by Hampe, Fresenius and other German chemists have not been translated.

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* Read at the stated meeting of the Chemical Section, held June 19, 1894.

For several years past I have given considerable attention to this subject. My analyses include the metal from the Lake mines, as well as copper obtained from Western mattes.

To the former, I found Hampe's original method* of analysis well adapted. This consists essentially in precipitating, by electrolysis, the greater part of the copper, and separating the metallic impurities in the usual manner from the remaining solution. The non-metallic elements, such as oxygen and sulphur, are determined in separate portions of the sample.

For obvious reasons it is not desirable to employ this method in analyzing electrolytically refined copper. Accurate results can be obtained by following the plan proposed by Fresenius,† but the separation of large quantities of copper by means of hydrogen sulphide, and the difficulty of accurately weighing bulky solutions, render this method very objectionable. A far more convenient process is the one recently published by Professor Hampe.‡ It is also more rapid than either of the two methods mentioned, and, with some modifications, it is especially well adapted for the analysis of most of the American refined coppers.

The process depends upon the removal of most of the copper as cuprous sulphocyanate.

The manner in which I practise it is briefly as follows:

25 grams of material are placed in a tall, lipless beaker and treated with a mixture of 200 cubic centimeters of water, 45 to 46 cubic centimeters of nitric acid (specific gravity 1·21), and 25 cubic centimeters of concentrated sulphuric acid (in case that much antimony or bismuth is present, as much as 100 cubic centimeters of H_2SO_4 may be taken). The beaker is covered and heat applied until nitrous fumes are no longer given off and the solution then diluted with 200 cubic centimeters of water to prevent the separation of copper sulphate. A rapid current of sulphur dioxide is now conducted into the liquid, the temperature of

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* Zeitschr. f. Berg, Hütten u. Salinenwesen **21**, 218, and **22**, 93.

† Zeitschr. f. analyt. chem., **21**, 229.

‡ Chemiker Ztg., 1893, **92**, 1691.

which is maintained at about 40° C. When the nitric acid is destroyed and the red fumes have disappeared, the liquid becomes turbid, owing to the precipitation of silver, selenium and tellurium. To insure the complete separation of the silver, a drop or two of hydrochloric acid may be added. After standing for twenty-four hours in a warm place, the solution is poured through a small filter into a graduated flask of two liters capacity. It contains bismuth, antimony, arsenic, iron, also nickel and cobalt, if these are present in the sample.

The sediment retained by the filter is composed of gold, silver, silver chloride, selenium, tellurium, possibly also lead sulphate, and traces of bismuth and antimony.

To determine the elements in the filtrate, the greater part of the copper must first be removed. To this end a measured amount of standard potassium sulphocyanate solution (1 cc. = ·05 Cu) is gradually added, whilst a current of sulphur dioxide is passed into the liquid. An excess of the sulphocyanate should carefully be avoided; it is preferable to leave some of the copper in the solution which should now emit a perceptible odor of sulphur dioxide. The delivery tube is withdrawn and rinsed off into the flask, the contents of which are then made up to the mark. To effect a thorough mixing it is well to pour the contents into a dry beaker, and to re-transfer them several times from one vessel to the other. The precipitate is allowed to settle and an aliquot portion, say 1,800 cubic centimeters, of the solution, filtered off. The separation and estimation of the different metals is effected according to the usual analytical methods. It is hardly necessary to state that the sulphur dioxide must be expelled before hydrogen sulphide is passed into the liquid.

In calculating the amounts of the metals contained in the entire liquid, we must allow for the volume occupied by the precipitate. According to Hampe the specific gravity of the sulphocyanate is nearly 3, and since twenty-five grams of copper would give about forty-eight grams of this salt, the volume of the latter would be sixteen cubic centimeters. The actual volume of the solution, therefore, is

2,000 — 16 = 1,984 cc. Suppose *e. g.* we had filtered off 1,800 cubic centimeters, and found in it ·020 gram of arsenic, then

$$\frac{1984 \times \cdot 02}{1800}$$

would be the amount of arsenic in the sample taken.

There yet remains to describe the analysis of the insoluble portion from which the main solution was filtered. It may contain, as I have already said, gold, silver (both in the metallic state and as chloride), selenium, tellurium, lead sulphate, and traces of bismuth and antimony, occasionally also copper.

It is best to detach, as completely as possible, the dry mixture from the filter, and to destroy the latter with fuming nitric acid in a small porcelain casserole. The detached portion is then added, and treated with the nitric acid till completely oxidized. After evaporation on the water-bath of the free nitric acid, the residue is digested with dilute hydrochloric acid, which leaves the silver in the form of chloride. This is filtered off, purified, and determined in the usual way. From the filtrate, selenium and tellurium may be thrown down by means of hydroxylamine hydrochloride. In the cold this reagent seems to have little effect, but upon warming, a reddish turbidity is observed which gradually collects in the form of dark flakes. These represent all the selenium and tellurium; they are collected on a tared filter, and dried at 105°-110° C. to constant weight.

I have not been able to effect a clean separation of the two elements. Approximate estimations were made by fusing the mixture in a current of hydrogen with potassium cyanide; the aqueous solution of the fused mass was then exposed to the air, which caused most of the tellurium to separate.

Gold, lead, and the traces of antimony and bismuth are obtained by the ordinary methods.

SMOKE-PREVENTING APPLIANCES.*

W. F. SICARD.

The attention of the writer having lately been called to the subject of smoke prevention, and becoming much interested in it, he has chosen this for the subject of a paper, thinking that it might interest the members of this section to discuss some of the devices proposed for this purpose.

While there seem to be an almost infinite number of devices for the prevention of smoke, many of them, if not nearly all, are practically untried. It is true that for nearly all the systems before the public, the inventors base their claims of efficiency upon the results of practical tests, but they are not always to be depended upon. It is by the results of continuous service, more than by special test that the merits of such an invention are proven, and it is usually the case that that system or device, for whatever purpose it may be, which is in the most general use is the best.

The question of the combustion of smoke, or, more properly, the prevention of smoke, is one of great interest to the engineer. The increased efficiency that will result from a more complete combustion of the fuel fed to a furnace, makes it an important object to scientific men to contrive some device whereby this end may satisfactorily be attained, and which, accordingly, must be simple, economical, durable and susceptible of regulation and control. That there are many inventors who claim to have solved this problem, the records of the Patent Office will attest, and doubtless many of them in a greater or less degree have done so, or at least have increased the efficiency of the particular boiler upon which they experimented.

There is such a vast difference, however, in the very foundations of their claims, and at the same time such a sameness in their results, and the methods of attaining those results, that one is almost bewildered. There are smoke preventers of every conceivable kind and variety, some of them simple, the greater number complex. There is no doubt that a cheap, simple and durable system that would give satisfactory results would be in demand, for in the fierce competition of these days every money-saving device must be employed. Of those at present on the market many are inefficient and practically untried. So many inventions are brought out before it has really been shown and proven that the results from their use are a gain or a loss, that manufacturers naturally hesitate before trying a new thing. Also, many of these systems are so exceedingly complex as almost to require the services of a man specially trained to operate them.

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* Read at the stated meeting of the Section of Engineers and Naval Architects of the Franklin Institute, May 23, 1894.

Smoke is defined for us as the combustible and uncombined products, produced in the imperfect combustion of coal, and which pass off from a furnace by way of the flues. Its principal constituents, and the only ones we need notice just now, are the portions of hydrogen and carbon of the fuel gases, that by reason of an insufficient supply of oxygen, have not been transformed into steam and carbonic acid, the ultimate products of the complete combustion of carbonaceous fuel. The hydrogen and partially burned carbon thus given off are invisible, but much of the carbon, when separated from the hydrogen in furnaces of faulty construction, changes from the gaseous to the solid state and becomes visible as a black, sooty body.

Coal is composed of a number of substances; the main constituents of all coal, however, are carbon and hydrogen, and these two in various combinations constitute the bituminous portion from which are derived the volatile products given off in the combustion of coal. The principal portion, however, is composed of carbon. The bituminous part of carbonaceous fuel becomes available for heating purposes only after its conversion to the gaseous state, while the carbonaceous portion is available in the solid state.

Carbon is susceptible of uniting with oxygen in two proportions, by which two distinct bodies, possessing distinct chemical properties, are formed. These bodies are carbonic oxide and carbonic acid. One of the most important facts revealed by the analysis of coal is the large proportion of hydrogen which bituminous coals contain. This may be roughly estimated at from five to six per cent., and it forms the main element of the evolved gases by the combustion of which flame is produced. Where coal is exposed to heat in a furnace the bituminous portions are volatilized and pass off. At the lowest temperature various condensible hydrocarbons are evolved. At the highest temperatures of distillation, permanent hydrocarbon gases and hydrogen are given off. After this distilling process, all that remains in the furnace is the fixed or solid carbon of coal, called coke, and mixed with it, earthy matter, the ash of the coal. The fixed carbon or coke remaining in the furnace after the volatile portions of the coal are given off, averages about sixty per cent. of the gross weight of the coal. As stated before, the hydrocarbons given off at the lowest temperatures, being richest in carbon, constitute the flame-making element of the coal.

A charge of coal, thrown upon a furnace fire, does not increase the general temperature, but lowers it and generates gases. On account of the amount of heat that is converted from the sensible to the latent state in this process, volatilization is a cooling process. So long as the bituminous constituents of coal are being evolved in quantity, the carbonaceous portion remains comparatively cool and useless as a heating agent. In short, the carbonaceous part has to wait for the heat required for its combustion until after the bituminous portion has been consumed.

The ratio of heating effect in the perfect combustion of coal compared with that evolved in imperfect combustion may be stated as about 15 to 4·5. Carbonic oxide is the result of imperfect combustion, and carbonic acid the result of perfect combustion of carbon. Combustion means union; in other words, the union of a combustible body with a supporter of combustion, in this case oxygen. At this point it may be interesting to note that coal gas is not inflammable; for by itself it cannot produce flame or support combustion in other bodies. A lighted candle in an atmosphere of coal gas will be extinguished.

Effective combustion for practical purposes depends more upon the air than the gas. This is so because we cannot control the gases while we can control the air that we supply to the furnace, and it is this control of the air that is the foundation of nearly all smoke-preventing devices. A good example of the unburnt gases in a flame is afforded by the common candle. In this, the tallow is first melted, then drawn up through the wick, and changed to a vapor, which has its temperature raised high enough to cause it to combine with the oxygen of the air, the heat of the combustion causing the separated carbon particles to become heated to brilliant whiteness. Around the outside is a filmy flame of this vapor and in the middle of it is a portion of gas which cannot be burnt for want of oxygen, which has no chance to reach it. If we supply oxygen to this flame by means of a blow-pipe, we greatly increase its temperature. In furnaces with natural draught, the volume of air required exceeds that required when the draught is produced artificially; an insufficient supply of air causes imperfect combustion, though an excess in the supply of air means a waste of heat. With very slow and uniform rates of combustion, nearly all the air required may be drawn through the grate; but if the rate of combustion be high, a great part of the air must be fed to the fuel above the grate, to consume the gases generated.

There are numerous cases in which, while dense smoke is given off with the furnace door closed, if it be opened slightly a great improvement in this respect will be noticed. At the same time, it has been conclusively shown, in certain classes of boilers, that while in realizing the highest power of a gaseous coal smoke is prevented, yet, in realizing the highest power of the boiler, smoke is made. The proportion of surplus air, the presence of which is required for the combustion of coal in ordinary furnaces in excess of the quantity which is chemically consumed, is diminished as the rate of combustion is increased, and the diminution of this excess is one of the reasons why the temperature of the furnace rises as the rate of combustion increases. This is shown in the following tests, the figures being from four different tests of different boilers and coals:

	Coal per square foot of grate per hour.	*Surplus air.*
Test 1, ...	2 to 4 pounds.	100 per cent.
Test 2, ...	7 pounds.	100 per cent.
Test 3, ...	10 to 16 pounds.	25 to 50 per cent.
Test 4, ...	20 pounds and upwards.	9 per cent.

In ordinary practice the rate of combustion for anthracite coal is from 7 to 16 pounds, and for bituminous coal 10 to 12 pounds, and with artificial or forced draught with blower, exhaust blast or steam jet, the rate may be increased from 30 pounds to as high as 120 pounds. It has been shown that in the marine boiler from 20 to 32 per cent. of the total heat of combustion is expended in producing the chimney draught, and, if we add to this the losses which will result from incomplete combustion and dilution of gases by excess of air, it will bring the total loss up to nearly 60 per cent.

From the foregoing statements, which express the results of practical tests, we are led to the conclusion that the cardinal principle of all smoke-preventing devices is, that in order to achieve complete combustion, and thus prevent the formation of smoke, the gases produced and air supplied must promptly and thoroughly be mixed. We have spoken of the relative volume of air required in natural and forced draught, and also of the various rates of combustion. In regard to the place of admission, above the grate, it has been found by test that the admission of air at the bridge of the furnace gives about 2½ per cent. better results than when it is admitted at the front of the grate. If the grate be not equally well covered with coal, the air admitted will enter in irregular streams through the uncovered parts, and be restricted at the time when it will be most needed. Of course, under such conditions, it bids defiance to all control and regulation, and as all that we can do towards effecting perfect combustion depends upon regulating the supply of air, the importance of having the coal on the grate well and evenly distributed is evident.

We will now proceed to consider some of the devices that have been proposed for smoke prevention.

In the first system which we will look into, the inventor states that his invention relates more particularly to obtaining practically perfect combustion of fuel in a boiler furnace, and to increasing the steaming capacity of the boiler, by preventing loss by the too free escape of heated gases, thus effecting economy in the use of fuel. He argues that heretofore the efforts that have been made to effect perfect combustion by means of forced draught have failed, because either too much or too little air under pressure was introduced to effect the required combustion, and because the heated products of combustion, principally carbonic acid gas and the nitrogen, the latter constituting the incombustible element of the air introduced, were allowed to escape too freely and at too high a temperature, thus carrying away the heat which should have been communicated to the water in the boiler and used to make steam. In this system the boiler is provided with a tight ash-pit and a tight furnace. Into the ash-pit is introduced a sufficient quantity of air under pressure to properly combine with the fuel, and no more. To prevent a waste of heat the smoke box is closed directly above the tubes, leaving only an opening of restricted but regulable area for the escape of the products of combustion. Into the furnace is introduced the proper quantity of air for the purpose of supporting combustion,

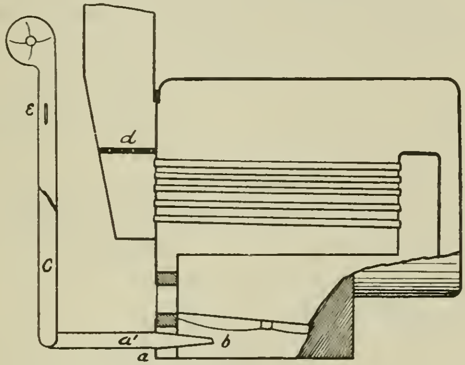

FIG. 1.

taking into consideration, and making proper allowance for, the nitrogen constituting the incombustible element of the air introduced under pressure, and taking from the furnace only the results of such combustion. To properly effect this result with a given weight of fuel per hour, the necessary volume of air to combine with this weight of fuel is introduced into the tight ash-pit, and the area of exit is adjusted in accordance with the principles stated. With this arrangement no chimney or stack is considered necessary, except when starting the fires, save such as shall serve to carry off the incombustible gases which reach the smoke box.

In the accompanying sketch, the parts are so easily distinguished as almost to need no explanation. The ash-pit is closed by the doors *a*, through which pass tubes *a'*, having nozzles *b*, preferably with long and narrow mouths, for delivering the air supply. The main supply pipe *c* is furnished with a damper *e*, by means of which the air under pressure may be shut off at will. The air pressure is furnished by a fan. The damper or diaphragm *d* can plainly be seen directly above the tubes and, when the boiler is steaming, this closes off the smoke box completely, except for the small apertures left for the escape of the incombustible gases. The system of operation is as follows: The fire having been lighted, air under pressure is admitted under the grate, the oxygen producing rapid combustion. Until the fire gains some headway, the damper *d* is left open, and the smoke and gas escape through the flues as in the ordinary system. As soon as combustion is fully established, the damper must be closed, thus closing completely the space between the tube sheet and the front door of the smoke box. There is still, however, an escape for the incombustible gases, through the holes in the damper before mentioned. By this means the stack is practically closed. The release of these incombustible elements is effected by the draught of the stack, as in ordinary practice, or by a steam blast, which may be placed, through the damper, to the base of the stack. This steam blast is considered necessary in the locomotive class of boilers, where rapid steaming and consequently rapid liberation of these incombustible gases is required. The inventor claims to have found that the best results are produced by placing the damper in the smoke box, almost immediately above the upper row of tubes, so that the heated incombustible gases shall be detained, or temporarily held back in the smoke box and below the water line of the boiler, before they are finally delivered to the stack through the holes in the damper. All the units of heat, temporarily retained below the water line, are conducted to the water and help to make steam, while those carried above the water line have the effect of superheating the steam. On these grounds he bases the claim that the damper placed in the chimney is not the equivalent of a damper placed in the smoke box near the water line. It may be interesting in this connection to append the results of a test recently made in Richmond, Va.:

Diameter of boiler,	48 inches.
Length of boiler,	14 feet.
Number of tubes,	49
Diameter of tubes,	2·75 inches.
Grate surface,	20 square feet.
Duration of test in each case,	10 hours.

	First Test, without Blower.	Second Test, with Blower.	Third Test, without Blower.	Fourth Test, with Blower.
Pounds coal used during test,	1846·75	1771	1591	1377
Pounds water used during test,	12715·74	13602·89	10078·45	10967·72
At temperature of	95°	95°	84°	81°
Evaporation to steam pressure of	75 lbs.	70 lbs.	69 lbs.	73 lbs.
Water evaporated from 212° to steam at atmospheric pressure,	15667·5	16704·34	12215·06	13654·81
Water in pounds, evaporated per pound of coal,	8·48	9·73	7·84	9·91
Saving in coal,		12·84%		20·88%
Air pressure in inches of water,				·75

These tests show a saving in coal of 12·84 per cent. and 20·88 per cent., respectively, and the engineer in charge of the tests mentions that there was an almost total absence of smoke even immediately after firing.

The second system is not so simple, and you will notice its complete difference from the former one. The object of this system is to effect the perfect combustion of smoke and gases generated in the use of bituminous coal and similar fuels, and also to increase the steaming capacity of the boiler. The inventor, in his description, says that, as understood by those familiar with boiler furnaces, the fuel gases enter the flues from the fire box in a partially consumed condition, and it is found that the water surrounding the flues partially cools them, thereby extinguishing the flames and causing the gases to pass through the flues in the condition of smoke. In cases where the gases arising from the burning fuel come in contact with air of lower temperature, the ignition of such gases is prevented, or, if ignited, the flame is liable to be retarded or even extinguished. This, he says, may be overcome by properly heating the air and then admitting it to the furnace, under proper conditions and in proper proportions, so that a practically perfect combustion will be obtained. It is also important that such heated air be introduced at the proper place. If it be introduced too near the boiler flues, it will readily escape and the result sought for will be lost. If, however, it be introduced at a point remote from the boiler flues, as, for instance, from above the furnace door to a little beyond the center of the fire box and above the bed of the fuel, and also in the bed of fuel, almost perfect combustion is attained and the intensity of the flames is increased. This will give an indirect course to the heated air and a better opportunity for its mixture with the heated gases. Hence the value of fuel does not depend solely on the quantity of air supplied thereto, but also upon the condition of the air and the manner of its application. Working upon these assumptions, they have constructed their furnace so that, if desired, the air may be supplied in three volumes, one of which enters the fire box through the grate bars, generates the gases from the coal, as in a gas producer, and partially consumes them. The other volume of air, which has previously been heated, enters through an air duct directly into the mass of burning fuel, mingling with the generated gases and partially consuming them, while the remaining volume of air, having also first been heated by passage through a coil of pipe over the fire box, enters the fire box, preferably at a point remote from the boiler flues, and mixing with the partially consumed gases completes their combustion and produces intense heat. The means employed for heating and introducing the air into the fire box are also utilized to increase the steaming capacity. For illustration, let us employ the sectional view of a locomotive boiler. The boiler is of the usual construction, with fire box, door for feeding fuel, grate bars and tubes, as placed in ordinary practice. In the fire box, arranged parallel to each other are an upper and lower series of water protected air tubes, extending from the tube sheet to above and below the door. As shown in the detail, they are practically three tubes combined in one. The smaller tubes are inside the larger one, and extend nearly the length of the fire box. They are secured within the larger tube by a series of plugs or nipples, about two inches apart. These plugs are first driven through perforations in the tubes, and there bored out, thus forming a passage for the delivery of air, at the same time securing rigidly together the three tubes. The center tube of the upper series will be noticed to extend forward nearly

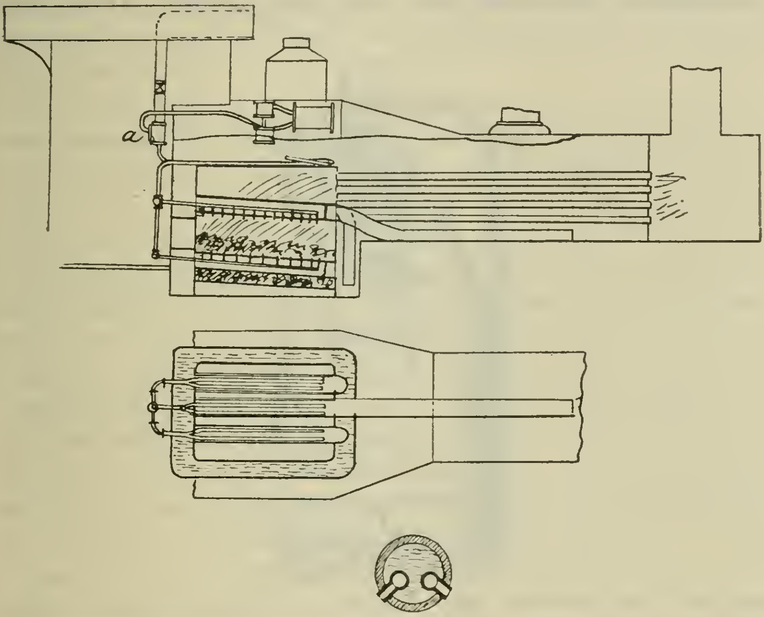

FIG. 2.

to the forward tube sheet, resting on the bottom shell of the boiler. This continuation conveys the cooler water immediately from the front, to and through the water jacket of the tube with which it is connected, quickly heating the same and enabling the boiler to rapidly generate steam. If desired, the ash pan may be entirely closed, and air furnished by the lower series of air pipes, which are directly in the bed of fuel, and thereby preventing the red-hot coals from dropping along the roadway. In the top of the cab is seen a chamber, opening at the front end to the atmosphere. Connecting this chamber with the air system is a pipe with an automatic valve, *a*, which cuts off connection between the chamber and system when air is being fed from the reservoir. The reservoir, suitably placed, is supplied with an air pump, and is also connected with the system at the automatic valve. Over the fire box is a coil of pipe, passing through which the air is heated on its way to the fire box. A serious objection to locomotives equipped with air-feeding mechanism is that when the locomotive is at a standstill the air supply ceases. In this case the objection is claimed to be obviated for the reason that

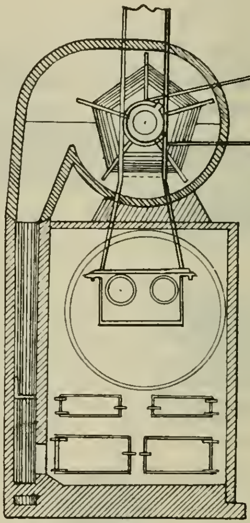

FIG. 3.

the air pump and reservoir can be thrown into action when the engine is not moving.

' The third system is again quite different from the others. The above sketch shows the boiler with stack and ash pit doors. On top of the boiler and in rear of the stack is a fan, connected to the stack by a duct or neck. The smoke and gases are drawn into the fan and forced down the side pipe into the ash pit. There is a door in the duct between the stack and fan, through which the supply of air is admitted. There is also a damper in this duct, by closing which and opening the ash pit doors, the boiler may be run under natural draught.

The last system we will mention is one that has been tried here in Philadelphia. This invention supplied the furnace (by the aid of two vacuum boxes and four pipes opening into the furnace above the burning fuel through which pipes were introduced) steam and heated air with great force, that mingled with the heated gases from the fire bed, and supplied the necessary oxygen for consuming said gases and promoting perfect combustion. Experiment had shown them that they obtained the best results by injecting combined steam and air, close to and in a horizontal plane over the burning fuel. By the use of *cold* air, the current supplied was at a normal temperature when it came in contact with steam, before the two were combined and injected into the furnace, with the result that the temperature of the steam and gases was greatly lowered; consequently, the combined volume of steam and air, when entering the furnace, was not at so high a temperature as it should be to effectually mingle with and ignite the gases. The necessity was thus demonstrated of using *hot* air, as the rising products of combustion would only ignite at a very high temperature. The air was heated, before entering the furnace, by a series of pipes containing auxiliary hot air vacuum chambers beneath the grate bars. This arrangement was tested here some years ago in the *Record* building. The results of the test were as follows:

	DAY RUN.				NIGHT RUN.			
	With Attachment.		Without Attachment.		With Attachment.		Without Attachment.	
	Boiler 1.	Boiler 2.	Boiler 1.	Boiler 2.	Boiler 1.	Boiler 2.	Boiler 1.	Boiler 2.
Coal used in pounds, . . .	840	840	1,260	1,260	1,122	1,176	1,680	1,680
Average steam pressure, .	64	64	55 to 60	55 to 60	63¾	—	57$\frac{3}{16}$	—
Ashes in pounds, ...	111	106	253	268	152	147	266	260
Water gauge, ...	2½	2½	2½	2½	2½	2½	2½	2½
Total coal used with attachment, ...		1,680 pounds.				2,298 pounds		
Saving in favor of attachment, ...	840 pounds or 33⅓ %.				1,062 pounds or 31⅗%.			

Two boilers, 80 horse-power each, running a Corliss engine. Length of boilers, 12 feet; diameter, 40 inches. Twenty-eight 4-inch tubes. Fire space, 42 x 60 inches. Fire box, from sheet of boilers to grate, 18 inches.

The four systems here described will suffice to illustrate how totally different are the ideas of their respective inventors, as regards the means to be employed in reaching the same end. Briefly summed up, they are as follows: The first supplies air under pressure; the second supplies heated air in a manner totally different from the first; the third essays to pass the smoke and gases through the furnace a second time; and the fourth supplies hot air and steam. Whatever be our opinions of the relative merits of these systems, they will afford us ample opportunity for discussion.

SHORTENING THE TIME FOR CORRECT SOUNDING.*

BY F. M. F. CAZIN.

When sounding is considered necessary, the ship's safety may depend on the shortness of time within which correct soundings can be made. If it were possible to correctly ascertain the depth of water below ship at the very instant when the lead strikes, and without relying on marks and deeps inserted in the sounding line, that is, without relying on correct observation of their color and correct counting of their number, when the line is hauled in; if the requirements of observation and action could be reduced to two signals, the one by the captain and the other by the man handling the line—the one being a command to let the lead, held at the water's surface, drop, and the other announcing that the lead has struck bottom—the interval between the two observed on the captain's time-piece telling at once the sounded depth, then precious seconds might be saved, on which the ship's fate is possibly depending.

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* Read by title at the stated meeting of the Section of Engineers and Naval Architects, April, 1894.

Such a possibility does exist, and the method of sounding that involves such a saving of time, when compared with present practice, has the further advantage of being both more convenient and more reliable, on account of being more simple, involving fewer causes for possible error, and relying on the observation mainly by the captain personally.

It is the purpose of these lines to demonstrate the possibility as stated, and to recommend its acceptance in practice jointly with the use of adequate standard tools in its execution.

The only tools required are a lead for shallow and normal depths, each of known density relative to the water of navigation and of precisely known length, both being accompanied by a pocket-tablet with figures for reference, which figures are of such nature as easily to impress themselves on the memory; the standard of leads being so selected that these figures remain of an uncomplicated kind.

In order not to unduly expand this statement, I must refer to some previous publications.

In the issues of the *Journal of the Franklin Institute* of March, April and May, 1893, the author stated and rendered proof of a natural law by him newly discovered, relating to the resistance by a liquid or gaseous medium to the movement of a solid therein. This law shows that a solid, when moving in a medium, causes a stated quantity of the medium to move in a direction inverse to the movement of the solid; and the law shows this quantity of the medium moved inversely, to be as the product of the volume displaced by first immersion by the distance of travel divided by the length of the solid, such length being measured in the direction of relative motion, and the distance, for which this stated quantity of the medium is moved inversely, is shown to be as the length of the solid, measured in the direction of relative motion. By introducing into theoretical mechanics the (also) new value

$$\frac{B}{d} = \frac{\text{Buoyancy}}{\text{Length}}$$

for "transverse average section," the newly discovered law was made serviceable for measuring the resistances to motion of ship, and the theoretical power required for propelling her. And it was also shown that aside of the quantity of the medium permanently and inversely moved by the movement of ship another stated quantity[*] of the medium is moved by the motion of ship, such other quantity returning to the position previously occupied without exercising any resistance or increasing power-requirement.

And finally, the author stated, as evolved from the same natural law, an equation

$$v = C = \sqrt{2\, g.\, d.\, \delta.\, \frac{\delta - 1}{\delta + 1}}$$

for the ultimate and uniform velocity with which any solid of higher specific gravity than the medium will finally fall in such medium.

This equation, having a direct bearing on the mechanical treatment of the ores of metals and on coal washing, the author dealt with, and with the practical consequences that must be drawn from it in metallurgical practice, in a paper "On Solids Falling in a Medium. I and II," published as part of the twenty-fourth volume of the "Transactions of the American Institute of Mining Engineers."

To the last-mentioned publication (generally accessible in pamphlet form) the author refers for the demonstration in detail of the correctness of the last stated equation.

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[*] This quantity is the product of the length of travel by the difference between the transverse major section of the solid and its transverse average section, which latter is as the immersed volume divided by its length, such length being measured in the direction of relative movement.

It was obtained by balancing the *inherent potential gravity* as cause of acceleration in the fall of a solid, expressed by

$$B \,.\, \delta \,.\, v \text{ Kgm—ms}$$

with the resistance by a medium to such fall, such fall resulting first in a modification of the acceleration g by

$$p = \frac{Q - P}{Q + P} = \frac{\delta - 1}{\delta + 1}$$

when

$$Q > P \text{ and } \delta > 1$$

as proven by the analogy with Attwood's results, when a weight in its fall raises a smaller weight, *such resistance to immersed fall* being determined by the new law, and the thereto truly relating Attwood law, and being then correctly expressed by

$$R = y \,.\, \frac{B}{d} \,.\, v \times \frac{v^2}{2\,g \times \frac{\delta - 1}{\delta + 1}} \text{ kgm — ms.}$$

B signifying buoyancy or displacement by first immersion.

d signifying length of solid, measured in the direction of relative motion.

v signifying velocity per second.

y signifying 1,000, as changing cubic-meters or metric tons, in which the value B would otherwise appear, into kilograms, and in consequence the total value into kilogram-meters, all values for distance, area or volume being expressed in meters.

δ signifying density of the solid.

For present purpose it is sufficient, if the statement is made that the distance any solid will fall in a medium with modified acceleration

$$= g\,\frac{\delta - 1}{\delta + 1}$$

(if, on account of higher density, it falls at all), is as

$$d \,.\, \delta$$

this is the distance, within which it causes to move inversely (this is to ascend) its own weight of the medium for the distance of its own length, and that the aggregate velocity with which this limited distance is passed is only one-half of the ultimate *uniform* velocity of submerged fall, or

$$\frac{v}{2} = \frac{C}{2} = \frac{\sqrt{2\, g\, .\, g\, .\, d\, .\, \delta\, .\, \frac{\delta - 1}{\delta + 1}}}{2}$$

such ultimate uniform velocity of submerged fall being for solids of any one specific form closely adapted in its longitudinal lines to the molecular division lines of the medium, as

$$C = \sqrt{2\, .\, g\, .\, d\, .\, \delta\, .\, \frac{\delta - 1}{\delta + 1}}$$

Of these two equations I propose to take advantage in a new method for sounding.

We may assume a sounding lead in the form of a cylinder with pointed ends, inclosed in a copper shell, being 0·1 m. long (*d* as one decimeter). The density relative to sea water is assumed as 11.

Such a lead will fall a distance

$$d\, .\, \delta = 0{\cdot}1 \text{ m.} \times 11 = 1{\cdot}1 \text{ m.} = 3{\cdot}6 \text{ feet.}$$

with a velocity of

$$\frac{C}{2} = \frac{\sqrt{2\, g\, .\, d\, .\, \delta\, .\, \frac{\delta - 1}{\delta + 1}}}{2} = \frac{\sqrt{19{\cdot}62} \times \sqrt{0{\cdot}10} \times \sqrt{11{\cdot}\frac{10}{12}}}{2} =$$

$$= \frac{4{\cdot}43 \times 0{\cdot}316228 \times 3{\cdot}028}{2} = \frac{4{\cdot}24 \text{ m.}}{2} = \frac{13{\cdot}9 \text{ feet}}{2} = 6{\cdot}95 \text{ feet.}$$

This means that the lead will first fall a distance of 3·6 feet, with a velocity of 2⅛ ms. or 6·95, virtually 7 feet, per second, or will use the first 1·1 / 2·12 or very nearly 0·5 second in falling 2·12 / 2 or 1 1/16 ms., or, as stated, 3·6 feet. And thereafter the distance will increase at the rate of 14 feet per second, giving for the first 1½ second of fall from the surface of the water a depth of 17½ feet.

But the time for observation relating to the same depth may be materially prolonged by selecting a lead of equal length but of lower density, the shell being only partly filled with metal.

Or even both length and density may be lessened, thereby causing longer time to be required for falling the same depth.

For a lead with d as 0·1 m. and as 6·4, we find the ultimate uniform velocity of submerged fall as

$$\sqrt{2g} \times \sqrt{d} \times \sqrt{\delta} \times \sqrt{\frac{\delta - 1}{\delta + 1}} = \sqrt{19{\cdot}62} \times \sqrt{0{\cdot}1} \times \sqrt{6{\cdot}4}$$

$$\times \sqrt{\frac{5{\cdot}4}{7{\cdot}4}} = 4{\cdot}43 \times 0{\cdot}316 \times 2{\cdot}53 \times 0{\cdot}8544$$

$$= 3 \text{ ms.} = 9{\cdot}84 \text{ feet.}$$

But a distance $d\,.\,\delta = 0{\cdot}1\,.\,6{\cdot}4 = 0{\cdot}64$ m., or 2·0992 feet. (2·1), is first fallen with a velocity of 9·84/2 or 4·92 feet, or 2·1 / 4·9 or 3 / 7 = 0·43 second are spent in the fall of 2·1 feet. And for every second of prolonged fall the depth from surface is greater for 9·84 feet.

Comparison may then be made between the action of the heavier and the lighter lead of the same length.

The heavier lead will reach a depth of 50 feet, using

	0·5	second for falling	3·5 feet, and
46·5 / 14 or	3·3	" " "	46·5
this is	3·8	" " "	50·0 feet of depth.

But the lighter lead will indicate the same depth, using

	0·43	second for the first	2·1 feet, and
47·9 / 9·84 or	4·86	" " " remaining	47·9 feet
using	5·39	" " " entire	50·0 feet

It is thus shown that, of the two leads of the same length but of different densities, the one of lower density requires 1·59 seconds more for reaching a depth of fifty feet, a difference, which further calculation shows to be increased at a depth of 100 feet to 10·38 — 6·7 or 3·68 seconds.

This difference in time required for falling a stated distance may be further increased by reducing aside of density also the length of the lead employed. With 0·06 for "d" we find by

$$\sqrt{0{\cdot}06} = 0{\cdot}245 \text{ and } 4{\cdot}43 \times 0{\cdot}245 \times 2{\cdot}53 \times 0{\cdot}8544 = 2{\cdot}346 \text{ ms.}$$
$$= 7{\cdot}69488 \text{ ft.}$$

as the ultimate and uniform velocity of fall. And with $d \,.\, \delta$ as $0{\cdot}06 \times 6{\cdot}4 = 0{\cdot}384$ m $= 1{\cdot}26$ ft. as distance for incipient fall with modified acceleration with an aggregate velocity of $7{\cdot}7 / 2 = 3{\cdot}85$ ft. per sd.; the time spent therein appears as $1{\cdot}259 / 3{\cdot}847 = 0{\cdot}33$ second.

This lead, therefore, will use in falling:

	3·85 feet		0·33 seconds
and for falling	46·15	46·15 / 7·7 or	6·00 seconds
or for falling	50· feet	will use	6·33 seconds

or 2·53 seconds more than the heavier and longer lead.

And calculation will show that, for a distance of fall of 100 feet, this difference will be increased to 12·82 — 6·7, or to 6·12 seconds; the lighter and shorter lead using almost double the time of that used by the heavier and longer one.

By varying the values for density and length, well adapted standard-leads may be selected for the use of navigators, that comply fully with all practical requirements, and the author would with pleasure assist makers of nautical instruments in perfecting such standard-leads under the protection of his rights as inventor.

Provided with such leads for sounding by time, the captain, with his time-piece in hand, may give the command, "Drop," by signal to the man holding the lead near the surface of the water, and the man may, by lifting one of his hands or by call, signal the instant when the lead strikes bottom, and the interval of time between the two signals, as observed on the time-piece by the captain, will at once tell the depth of water below surface, the captain having in his memory a few simple figures or consulting a pocket-tablet instead.

Except in time required, the old and new methods vary in this also, that under the older method the length of line spent is exclusively relied upon, while the spending of this length depends on other conditions also, besides the depth of water, while under the new method this cause of error is avoided, and a more reliable basis of conclusion is utilized, namely, that of vertical fall and time spent therein, which is regulated by a law of nature independently of all causes of error, as long as free fall is resisted by the water only and not by any action of the sounder.

Navigators testing the new method aside of the old will probably not hesitate to accept the new one. As in the use of the sextant, simultaneous observation with either similar or different leads will be a safeguard against error of observation. And so precise and rapid is the sounding under the new method, that simultaneous sounding at bow and stern on an ocean steamer will at once tell the direction and degree of falling off in depth on the steamer's course. Any communication on the subject from those practically versed in matters of navigation will be most thankfully received by the author.

HOBOKEN, N. J., March, 1894.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 20, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 20, 1894

MR. THEO. D. RAND in the chair.

Present, forty-three members and three visitors.

The Actuary submitted the following propositions for amendments to the by-laws of the Institute, recommended for adoption by the Board of Managers at its stated meeting, held Wednesday, May 11, 1894, viz.:

Resolved, That the Board recommends to the Institute an increase of the annual contribution of members to $8, and of the annual payment on second-class stock to $6, and of the fee for life membership to $100.

Resolved, To effect this that the Board recommends the adoption of the following amendments to the existing by-laws of the Institute:

That article ii, section 1, paragraph 4, be amended by striking out the words "three dollars," and inserting in place of them the words "six dollars."

That article iii, section 6, be amended by striking out the words "fifty cents," and inserting in place of them the words "seventy-five cents."

That article iv, section 1, be amended by striking out the words "five dollars," and inserting in place of them the words "eight dollars," and further by striking out the words "fifty dollars," and inserting in place of them the words "one hundred dollars."

That article iv, section 4, be amended by striking out the words "fifty cents," and inserting in place of them the words "seventy-five cents."

The Secretary presented, on behalf of Mr. Henry R. Heyl, the following additional amendments to the by-laws:

ARTICLE XVII.—Amendments. Shall be amended to read as follows:

Amendments to these by-laws to be proposed at any stated meeting, shall be posted upon the notice board by the first of the month. Such proposition, when presented to the meeting, may be considered, and amendments thereto submitted, but action thereon shall be deferred until the next stated meeting, and, pending action, the proposed amendments shall remain posted upon the notice board.

It shall require the votes of two-thirds of the members present to adopt any amendment to these by-laws, except in the case of article ii, relating to capital stock, which cannot be altered unless by a vote of a majority of the stock represented at the meeting.

ARTICLE III.—Members. Shall be amended to read as follows:

SECTION 1. The members of the Institute shall consist of manufacturers, mechanics, artisans, and persons friendly to the mechanic arts, and they may be either annual contributors, life members, permanent members, holders of second-class stock, honorary or corresponding members.

SECTION 3. The privileges of membership in the Institute shall extend only to persons of legal age, who are not in arrears and who shall have signed the charter and by-laws.

ARTICLE IV.—Payments. Shall be amended to read as follows:

SECTION 1. The annual dues of contributing members shall be eight dollars; a life membership (not transferable) may be acquired by the payment of one hundred dollars within any one year, and a permanent membership may be granted to any one who shall, within any one year, contribute to the Institute the sum of one thousand dollars, which membership may be transferred by will or otherwise.

SECTION 5. The annual dues from contributing members may be applied to the current expenses of the Institute, but all moneys received from life and permanent membership shall be vested in the Board of Trustees, the income therefrom only to be applied to the maintenance fund.

On motion of Mr. Chorman, duly seconded, the foregoing amendments were ordered to publication in the manner prescribed in the by-laws, so that they may be formally acted upon at the stated meeting in September next.

The meeting then proceeded to the technical business announced on the programme, namely, the discussion of the subject of the injury to underground metal pipes by electrolytic action due to leakage of the return current from the trolley lines.

The Secretary introduced the discussion by some informal remarks bearing on the history of the subject, and exhibited a number of photographic pictures of iron, gas and water pipes, lead-covered electric cables, etc., from various cities, which showed extensive corrosion, and in some cases actual perforation from this cause. The subject was then discussed by Messrs. I. H. Vail, of New York; Dr. E. J. Houston, E. A. Kennelley, A. Langstaff Johnston, James M. Price, Carl Hering, Wm. McDevitt, and the Secretary. (The discussion will appear in the *Journal* in due course.) Mr. Price exhibited a new rail joint and bond specially adapted to reduce the leakage to a minimum. Mr. Johnston also exhibited the manner of bonding adopted at his suggestion on the Hestonville Electric Railway, in Philadelphia. The Secretary presented, on behalf of Mr. Vail, a fragment of a large water pipe, extensively corroded and perforated by the leakage of current from a trolley line after two and one-half years' exposure to this influence.

The Secretary exhibited and described for Messrs. Wood & Comer, of Philadelphia, an improved multiple distillation apparatus for laboratory use, by which a number of distillations may conveniently be conducted at the same time. In his monthly report, he gave an account, with illustration, of a new product called "cube ice," devised by Mr. Vander Weyde, of London, in the manufacture of which the inventor has taken advantage of the property of "regelation" to make blocks of artificial ice composed of small cubes, which block on being struck with a mallet breaks up into its constituent small cubes. As each of these bears the trade-mark of the manufacturer, the purity of the product can thus be depended upon.

The Secretary gave a *résumé* of the conclusions of the Committee on Science and the Arts on the merits of the American Gas Furnace Company's system of generating and utilizing fuel gas, and on the electrolytic white lead of Mr. Tibbits, of Hoosic, N. Y.

Adjourned. WM. H. WAHL, *Secretary.*

BOOK NOTICES.

Lectures on Mathematics. Delivered from August 28 to September 9, 1893, before Members of the Congress of Mathematics held in connection with the World's Fair in Chicago, at Northwestern University, Evanston, Ill. By Felix Klein. Reported by Alexander Ziwet. 8vo. Price, $1.50, net. New York and London: Macmillan & Co. 1894.

In this book we have an account of some of the principal advances that have been made in mathematics since 1870, by a man who has contributed largely to this advancement both by his teachings and writings. It is to this latter fact that the great charm of the book is due. For, as is stated in his account of Lie's work, Professor Klein's knowledge of these new ideas has been gained while the ideas were in process of formation, thus giving a mastery of the subjects dealt with, that few who have not grown up with them can ever hope to gain.

The subjects treated are those which are especially characteristic of the period considered. In fact, the book may be said to be an exposition of the application of geometrical methods to analytical problems. On every page the reader is reminded of the very healthy tendency in modern mathematics of forming a mental image of every step, that is, of assigning a geometrical meaning to every operation.

The matter of the book is divided into twelve lectures and an appendix. Lecture I deals with the work of Clebsch on the Abelian integrals and on the theory of invariants. Lectures II and III treat of the work of Lie on his sphere geometry and contact transformations with reference to their applications to differential equations. Lecture IV, on the real shape of algebraic curves and surfaces. Lecture V, theory of functions and geometry. Lecture VI, on the mathematical character of space intuition and the relation of pure mathematics to the applied sciences. Lecture VII, the transcendency of the numbers ε and π. Lecture VIII, ideal numbers. Lecture IX, the solution of higher algebraic equations. Lecture X, on some recent advances in hyperelliptic and Abelian functions. Lecture XI, the most recent researches in non-Euclidean geometry. Lecture XII, the study of mathematics at Göttingen.

The appendix consists of a translation by Professor Tyler, of a sketch by Professor Klein, of the development of mathematics at the German universities.

On concluding the book, the reader cannot help wishing that the number of lectures had been greater, since they are particularly valuable to American readers, as the object of Professor Klein was to supplement the views on these subjects that he found prevalent in America.

Every student of mathematics should read these lectures, since in them we have the ideas of a great mathematician expressed in a way that would be impossible in a systematic treatise. The lectures being informal talks, the individuality of the lecturer had full sway, and the reader feels that he is closer to the author than if the latter were seen only through a mass of formulæ.

A feature of great importance in the book is the numerous references to original memoirs, thus enabling the student to follow in detail the course of development outlined in the lectures. E. A. P.

Tables for the Computation of Railway and Other Earthwork. Computed by C. L. Crandall, C.E., Associate Professor of Civil Engineering, Cornell University. New York: John Wiley & Sons. 1893. Second Edition. Price, $1.50.

In the method for which these tables are intended, the volume of a cutting or of an embankment is first found approximately by averaging the end areas, and then, if desired, a prismoidal correction can be applied. A table of such corrections is given, as is also a table of volumes by averaging and areas.

In this second edition, the text has been entirely revised, and the author has added a proof of the prismoidal formula, a comparison of that formula with others, a formula for correction for curvature, and rules for irregular cross-sections. T.

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE GRAPHICS OF THE EFFICIENCIES OF THE STEAM ENGINE.

BY R. H. THURSTON,
Director of Sibley College, Cornell University.

Among the many fragments of Rankine's work on the economics of the steam engine which have been left us as nuclei of later detailed and more complete studies, none, perhaps, better illustrates the remarkable perspicacity of the man than his statement of the principle properly governing the adjustment of the best ratio of expansion, and his exemplification of that principle by the application of the touchstone of financial result. James Watt, a century ago, and more (1782), patented his invention of the use of the expansive action of steam in the engine, with the purpose of effecting the most economical possible conversion of thermal into dynamic energy; but he was never able to secure those gains in the practical operation of the machine which his mathematical computations had indicated as scientifically possible and as practically obtainable. A hundred inventors since the time of Watt have wrecked their fortunes, and thousands of engine builders and users have met with disaster, striking on the same rock. The vast discrepancy between the seemingly exact and positive predictions of the thermo-dynamic and mathematical theory of the engine and its practical results in everyday work have seemed to all the early engineers too great to be attributed to other than defects of construction and to errors in restricting the expansion of steam or in so constructing the machine as to make it impracticable to secure at once considerable expansion and steady motion. For a century it thus happened that efforts were constantly being made by inventors and builders to find some way of grasping that immense profit which was apparently just within reach by the simultaneous rise of steam pressures and the expansion ratio. It is only recently that we have learned precisely where the difficulties lie, and what must be the direction of improvement to insure the remedy of the still existing defects and further approximation to the thermo-dynamic conditions and to those results which are the ultimate object of every great invention relating to this wonderful machine.

Watt discovered the facts which are now known to constitute the obstacle to success in the endeavor to carry out his principle and to gain full advantage in transformation of the heat-energy stored in steam; but he exhausted all his ingenuity in the endeavor to remove what he thought the main barrier to complete utilization of his idea—irregularity of action of a piston subjected to varying pressures—and probably never discovered that, with ever so smooth a motion, profitable expansion must be enormously restricted by that phenomenon, the investigation of which was the subject of his very first experiments with the old Newcomen model of the University of Glasgow. It was reserved for Daniel Kinnear Clark, in England (1852), for Hirn, in France (1855), and for Isherwood, in the United States (1860), to show that the primary source of this restriction of profitable expansion was to be found in the fact that the internal wastes by condensation of steam, consequent upon the heat-conducting character of the cylinder walls—to "cylinder condensation" as it is now generally, though, perhaps, inelegantly, termed—increase more rapidly than the gain by expansion, thus giving a low ratio of maximum economic value. Rankine and Clausius, and Thomson and Zeuner, built up the whole thermo-dynamic theory of the heat-engines; but it was only after a quarter of a century had passed that the differences between the ideal and the real heat-engines came to be fully understood, and that their effect upon the economical working of the machine was recognized. Rankine earned added fame by his declaration of the principles of finance bearing upon the case and by showing that here, as in every other task set the engineer, the results must be gauged by the final measure of all engineering—the work accomplished by the unit of coin paid out; but the effect of the Watt phenomenon did not enter into his computations, and its extraordinary effect upon the proportions of the steam engine remained to be revealed by the work of the last and the current decades. The essential principles affecting the proportions of the engine which will give the best results, all things considered, are probably all now familiar to every well-informed engineer and to many contemporary thermo-dynamists; and the exact methods of investigation of the subject will become equally familiar to all when the now numerous researches in the physics and the economics of the case, now in progress in the hands of numberless engineers and men of science, shall have fully revealed the data needed for their development.

Graphical methods of representation are usually more intelligible to the engineer than are the algebraic processes; and this is especially true of the engineer whose genius lies in the direction of invention and of construction, rather than of theoretical investigation, and where the conditions to be studied and examined with reference to their relative interactions are numerous and where those mutual influences are obscure. An algebraic equation gives, in its solution, a single isolated datum; a curve in a diagram, the equation of which curve is known and permits its construction, exhibits an infinite number of successive values simultaneously, and illustrates, at the same time, the method of variation of those data and the presence or absence of maxima and minima. The diagram itself may present to the mind at a single glance the whole succession of phenomena in a series, or a complete cycle of operations involving the solutions of various equations, and for numerous different values if algebraic methods are adopted for the case. A half-dozen computations and a few strokes of the pencil, on the other hand, reveal, often, all the details of operation of a complicated system, and tell just where and how the engineer may look for results of maximum possible value. For the cases to be studied in the present instance, we shall probably find graphical methods the only practically available system of revelation of the information and the facts sought. It is for this reason, and because they are also vastly more satisfactory in their legibility and comprehensiveness, that they are adopted in the work which follows.

The Distribution of Energy supplied the steam engine is easily stated in a general way; but the exact distribution into utilized power and wasted energies is not always readily ascertainable, even with modern facilities for their measurement. Assuming this analysis to have been effected in any given case, as for a modern "high-speed" engine of moderate power, and working with high steam-pressure, some such balance-sheet as the following would be obtainable. Should the columns fail to balance, it would indicate either that a false measurement had been made, that the errors of careful observation, even, were sensible and perhaps cumulative, or that some source of waste had escaped observation altogether, as often did, in fact, the internal thermal wastes, during the greater part of the history of the machine, and up to within a few years.

BALANCE SHEET OF HIGH-SPEED ENGINE.

RECEIVED.	*Per cent.*	EXPENDED.	*Per cent.*
Energy stored in steam produced in the boiler and transferred to the engine	100	Utilized by conversion into dynamic energy at the engine .	9
		Wasted by friction	1
Total	100	Indicated Power	10
		External thermal waste	2
		Thermo-dynamic wastes . . .	60
		Internal thermal waste	28
		Total	100

Of the several quantities in the right-hand column, the first is easily and exactly calculable, as it is a purely thermo-dynamic problem, and capable of precise solution. The second item may be approximately computed, or deduced by reference to the experimental determinations of friction losses exhibited in the operation of similar engines. The first is the dynamometric or "brake" power of the engine, and the second is measured by the difference between the "indicated" and the "brake" powers. The fourth is heat lost by conduction and radiation, and may be computed or observed in any case with sufficient accuracy for all practical purposes of the engineer, and for the present case. The fifth is the necessarily rejected heat of the thermo-dynamic operation, is dependent upon the cycle adopted, the range of temperature worked through in the conversion of energy, and is precisely computable. The last, the internal wastes of heat by "cylinder condensation," may be accurately measured in the case of the engine constructed and in operation, and can be approximately computed or may be deduced by reference to the performance of other engines, where the results sought are for the case of an engine proposed and to be designed. We make these measurements or computations, or both, for any number of sets of conditions, and may establish a curve for each of these elements of the problem, the ordinates of which may be made the costs of the energy represented, and the abscissæ may be taken as the measures of the steam used or any convenient quantity defining the conditions of the case, as, in the cases to be here used in illustration, the ratio of expansion adopted, unity weight or volume of steam being always taken into the engine at the point of cut-off.

The measure of cost here to be taken is the number of pounds of steam demanded per horse-power per hour to supply the energy utilized or wasted, as the case may be. With steam at a pressure of 120 pounds absolute, 105 by gauge, nearly, and with a back pressure of three pounds above vacuum, clearance being negligeable and the engine well jacketed, the quantity of steam demanded for efficiency unity would be about two and one-half pounds per hour per horse-power, and, for any other efficiency, 2·5 divided by that efficiency, nearly. This quantity, as computed for the ideal case, the ratio of expansion being fixed, is invariable and incapable of modification by any human power. The wastes, other than thermo-dynamic, which latter waste is also inalterable, are capable of amelioration by various expedients, some of which are easily applicable, others difficult and as yet impracticable.

It is thus evident that it is by the amelioration of wastes in the ordinary steam engine that we are to advance in its improvement, if at all, aside from the gain to be effected by that increase of temperature range in expansion, which is the method of thermo-dynamic improvement available. It is in the reduction of extrathermo-dynamic wastes that we are to seek the most fruitful ways of promoting the economy of operation of the heat-engines of whatever kind, while the increase of thermo-dynamic efficiency and the reduction of thermo-dynamic losses will probably occur continually, but slowly, up to some as yet undetermined limit, which limit is, nevertheless, probably not very far distant. Both the thermo-dynamic improvement and the gain by reduction of extra thermo-dynamic wastes must be looked upon as legitimate ways of further improvement of the steam engine as a heat-engine, as a transformer of thermal energy into dynamic form; but the inaccessibility of the zero of the absolute thermometric scale renders the former comparatively unpromising of result, while the interception of external heat losses, the abolition of internal heat wastes due to the heat-conducting character of the cylinder walls, and the elimination of friction, are at present more simple and promising directions of advance.

As will be presently seen, each of the extra thermo-dynamic wastes becomes a larger and larger tax upon the thermo-dynamic machine as the latter becomes more efficient through extended expansion, and each, acting by itself, would, if carried sufficiently far, place a limit to economic heat-conversion by such expansion; which limit is the earlier reached as the waste is greater. Thus, with prolonged expansion, a time would always come when further expansion of the steam would develop less power than would be, at that instant, required to overcome the resistance of friction; and, from that point on, the power exerted by the machine upon the working machinery would be a negative quantity. Similarly, external wastes of heat might, beyond a given ratio of expansion, amount to more than the quantity usefully converted, and efficiency would thus again be made negative. Internal heat wastes in this manner render the total ultimate efficiency of the engine a negative quantity at a comparatively early stage in expansion, as these wastes are great at low ratios even, and are a rapidly increasing fraction of the energy supplied with increasing expansion. Thus the magnitude of the ratio of expansion at which final total efficiency becomes a maximum is a gauge of the extent to which avoidable forms of waste exist in the engine, and of the success attained in the design, construction and operation of the engine. That engine which gives its best effect at the highest ratio of expansion is, other things equal, the best engine, viewed from the standpoint of physical perfection. This is perhaps best shown by the diagram herewith presented.

In figure 1, let the ordinates of the various curves be made proportional to the weights of steam employed per horse-power and per hour, under the conditions assumed in the construction of each of the several curves, and let the abscissæ measure the simultaneous values of the ratios of expansion in the given engine, and with the initial and back pressures, as here assumed—120 and three pounds, respectively, above vacuum. Compute, first, the quantity of steam required for the "ideal case" at each of these ratios of expansion, and construct the lower curve of the series by passing it through the several computed points. Similarly, compute, or find by reference to results of experiment, the additional and total quantities demanded for the engine when the wastes due friction are taken into account, and thus obtain the second curve. Next add the weights of steam required to supply the heat wasted externally by conduction and radiation, and, as a final determination, find the internal wastes by the action of the cylinder walls, thus ascertaining the locus of the upper limiting curve of the series.

The lower line is obtained by the method of Rankine, and accurately represents the efficiencies and the costs of power for the ideal representative case taken. It is seen that the steam expended varies from about 40 pounds per horse-power and per hour at full stroke, to 20 at 3·5 expansions, to 16 at a ratio of expansion of 5, to 12 at 12 expansions, and about 10 pounds at a ratio of 20. The gain continues indefinitely, but at a decreasing rate, until a ratio of about 40 brings us to the limit at which the expansion line begins to fall below the back pressure line. Were there no wastes of extra thermo-dynamic character, this would be the method of operation of the engine which would insure highest efficiency and highest "duty." The friction loss in the case here taken, costs a quantity of steam which is decreased with the enhanced efficiencies of higher expansions, is but little affected by changing loads and power, and which, as a percentage of ideal costs, increases constantly with increasing expansion and decreasing power. It is thus found to place a limit to gain, as here taken, at about twenty-five expansions, and adds, throughout the whole range, not far from three pounds of steam per hour and per horse-power to the costs of useful work. External heat wastes still further exaggerate costs and restrict the profitable expansive action of the engine and a ratio of twenty is found on the curve to be as much as can be employed to advantage when all these wastes are taken into account. Finally, taking up the internal heat wastes by action of the metallic surfaces enclosing the fluid, and assuming, as here, that the engine is of such size and character as to waste, in spite of jacket-action, from twenty per cent. at full stroke, to fifty per cent. at seven expansions, and still higher proportions at greater ratios, the proportions found actually wasted in, for example, the Sandy Hook experiments reported by the writer to the A. S. M. E., some years ago, it is found that a maximum efficiency is attained, as shown on the upper line, at about seven expansions, or at the point experimentally found for a more efficient engine, operated at a lower pressure, by Hirn and Hallauer. This is probably as large a loss, and gives as radical an illustration of the facts of such cases, as can be fairly expected. No well-designed and properly constructed engine should give a higher curve of final efficiency than is here presented, unless of very small size or working under peculiarly disadvantageous circumstances.

Whatever the form or dimensions of the engine, such construction of its several elements of efficiency as is here exemplified will exhibit the facts in which the designer is most interested, and show the costs of power and the most economical adjustment for high duty. All the thermodynamic, and all the thermal, and all the dynamic elements are here brought into view, and all measures are taken by a common and intelligible scale. The scale actually to be adopted will depend upon circumstances. Where the steam is supplied under different conditions, and thus may have a variable measure of intrinsic or conventional value, the vertical scale should be made in thermal units, rather than weights of steam. In some cases it should be made a scale of coal-weights, while in the solution of some of the most important problems presenting themselves to the engineer, this scale should be one of money-costs.

The Comparison of Various Types of Engine may be made by these graphical methods with the greatest ease and with most satisfactory results. Every essential element of economical operation being thus capable of representation on a common scale, the construction of such a diagram as is here illustrated and described for each permits the selection of the machine likely, on the whole, to prove best; and we are thus enabled to identify the best adjustment of each and to make the comparison of a pair or of a series of available designs under their several individually best conditions of working. Adhering to the case thus far studied, that of the simple engine, it may be required to ascertain which of a number of machines of stated and required power, but differing in proportions of stroke and diameter of cylinder, or in speed of piston and of rotation, or even simply in clearness, is most desirable. The construction, on a common scale, of a set of these diagrams will reveal to the eye and at a glance the probably best design. The loss by clearance is treated precisely like the wastes by external loss of heat or by internal condensation or leakage, and all may, as in fact illustrated above, be taken as a common internal waste, since it often happens as here that they cannot well be separated with exactness. The best practical method of making the comparison is perhaps that of making the diagrams on tracing paper or cloth and superposing them, one upon the other in pairs, eliminating, one after another, the least desirable cases.

Compound or "Multiple-Expansion" Engines afford the most interesting and probably the most useful applications of such methods of graphical representation of problems of this sort. In such comparisons as have been just referred to, when multiple-expansion, series-expansion—or cascade-expansion, as French writers sometimes call it—is to be considered, it becomes especially important to ascertain not only what relations of efficiency exist at the best adjustment of each, but often even more important to determine the method of variation of efficiencies with varying expansion, and the relative values of each type throughout their respective as well as their common ranges of working. This process of complete study which, ordinarily, is most laborious and troublesome—when, especially, their respective best conditions of operation are to be identified and compared—becomes easy, interesting and exact when the graphical process can be accurately carried into effect. It then

COST-VARIATION DIAGRAM FOR VARIOUS TYPES OF STEAM ENGINE.

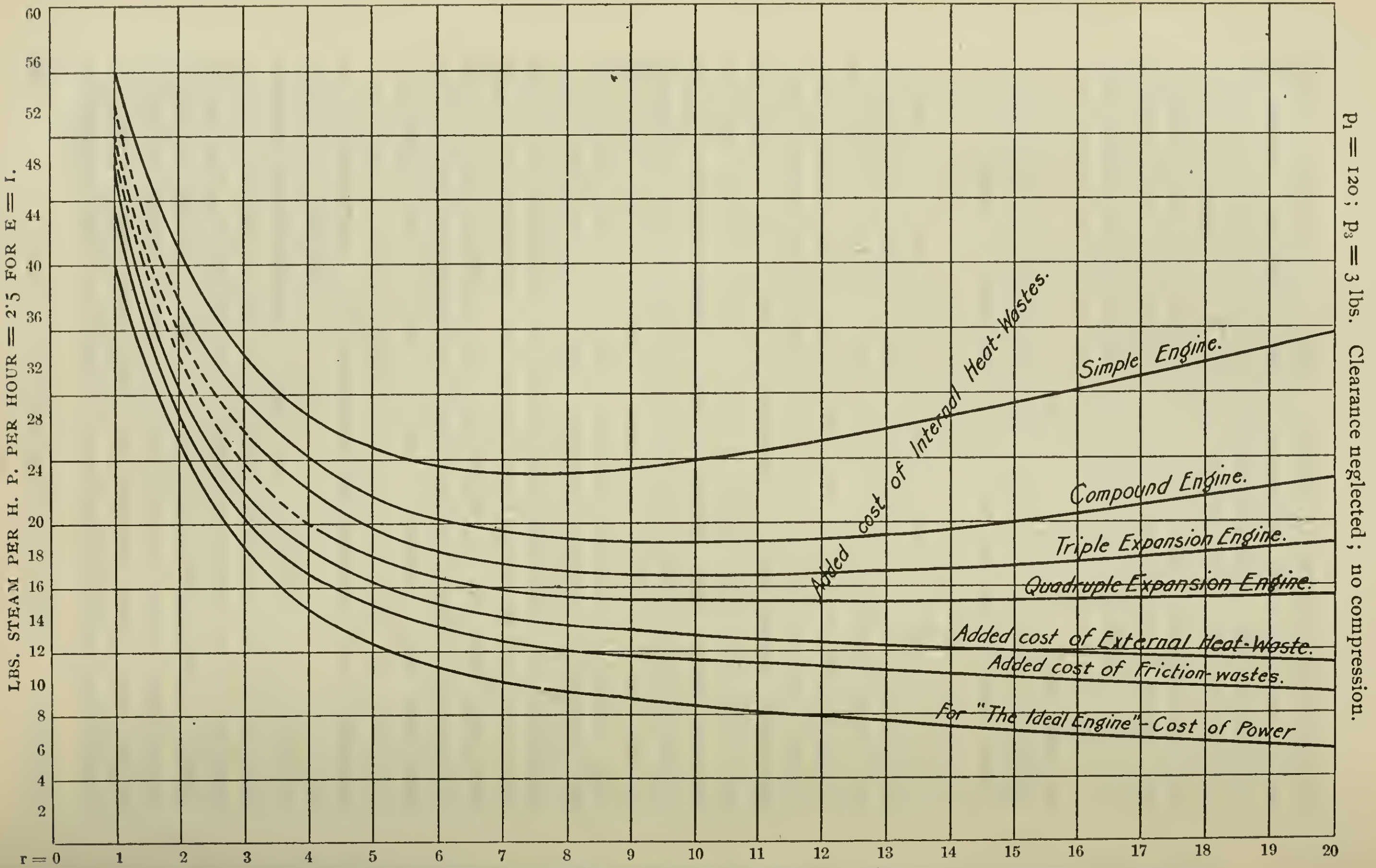

FIG. I.—STEAM DRY AND SATURATED THROUGHOUT THE STROKE.—ENGINES EFFECTIVELY JACKETED.

becomes as easy to discover the best ratios of expansion, and the ranges of working throughout which the simple engine is inferior or the more complex structure is superior, as to find absolute values for specified single cases. But it is in the exhibition of the relative values of the several multiple-cylinder engines that this process is perhaps likely to prove of most service and to best illustrate the essential principles involved.

In the action of the multiple-expansion systems, the several lines of our diagram become altered in location, although retaining their distinctive forms. The ideal case only remains unaffected, the thermo-dynamic conditions being the same. The friction-line is usually, but not always or necessarily, raised; the friction of the machine being in some cases substantially unaltered, and in others even reduced, by modifications of designs introduced by "compounding." In the "tandem-compound" engine, this change is often insensible or unimportant; in the three-crank compound this dynamic waste may be even reduced by the balance secured about the shaft-line. The external thermal wastes may be but slightly affected also, the reduction of the mean temperature of the external surfaces of the cylinders compensating roughly the extension of area. The internal heat wastes are most remarkably modified in good examples of such engines. The upper line of our diagram is brought down considerably and often very far below that location given it in the case of the companion simple engine. These wastes may be reduced from six or eight pounds, for example, to three or four in the compound, to two or three in the triple-expansion, or to even less weight of steam per horse-power and per hour, in the more complicated forms of engine, for similar total ratios of expansion. The restricted expansion in each of the cylinders and the reduced area of actively wasteful cylinder-wall, make the condensation of the entering steam much less than at the point of cut-off in the simple engine, and the steam thus condensed, being re-evaporated completely at its exit, enters the second cylinder in series as steam once more, is there again subjected to similar condensation, and thus goes on through the series, however extensive, the waste from the one cylinder more or less completely meeting the demand for wastes in the next, and thus approximately reducing the total waste from this action to that comparatively small fraction of the steam supplied from the boiler, which is represented by the comparatively small condensation in a single cylinder of the series. Every step thus gained in the reduction of these internal thermal wastes permits corresponding advance to be made toward full utilization of the thermo-dynamic gain due expansion and raises the ratio of expansion for best effect.

In illustration: let the same thermo-dynamic case be assumed; the expenditures of steam being computed by the familiar equations for efficiency, and taking the consumption of steam to be 2·5 pounds for efficiency unity; giving, for any given ratio of expansion, not far from $w = 40 / \sqrt{r}$, as the minimum cost in steam expended, as before, for the ranges of expansion usual with such engines. Take the friction as unchanged and the external losses of heat as substantially constant, the one amounting to about ten per cent. of the rated power of the machine and the other as one-third that proportion, at that rating, and varying as in the case of the simple engine. Following experience with the most successful designs of mill-engines, and comparing cases in which the double-expansion engine reduces the internal wastes to one-half, the triple to one-third, and the quadruple to nearly one-fourth the magnitudes distinguishing our simple machine, we obtain the three curves in the figure lying between the upper line already obtained and the lower three lines of the diagram as first traced.

In each case we find the internal heat wastes constituting a heavy tax upon the operation of the engine; in each they become a larger proportion of total expenditures as the ratio of expansion becomes greater; in each case the point of minimum expenditure and the ordinate of maximum efficiency recede further from the best ordinate for the simple machine, as these losses become less; and, as already remarked, the ratio of expansion for highest total effect becomes a gauge of the value of the type of engine studied. While the simple engine did its best work at a ratio of 7—all these machines are assumed to be jacketed—the compound raises the figure to 10; the triple-expansion to 12 or 13, and the quadruple-expansion engine does its best duty at a ratio not far from 18. With larger and faster engines, these values of the ratio of maximum effect will be found still more distributed, and will assume still higher values; but 7 or 8, 10 to 12, 13 to 15, and 18 to 20, are probable fair maxima, respectively, in modern good practice with the assumed pressure, for the several types of machine above taken.

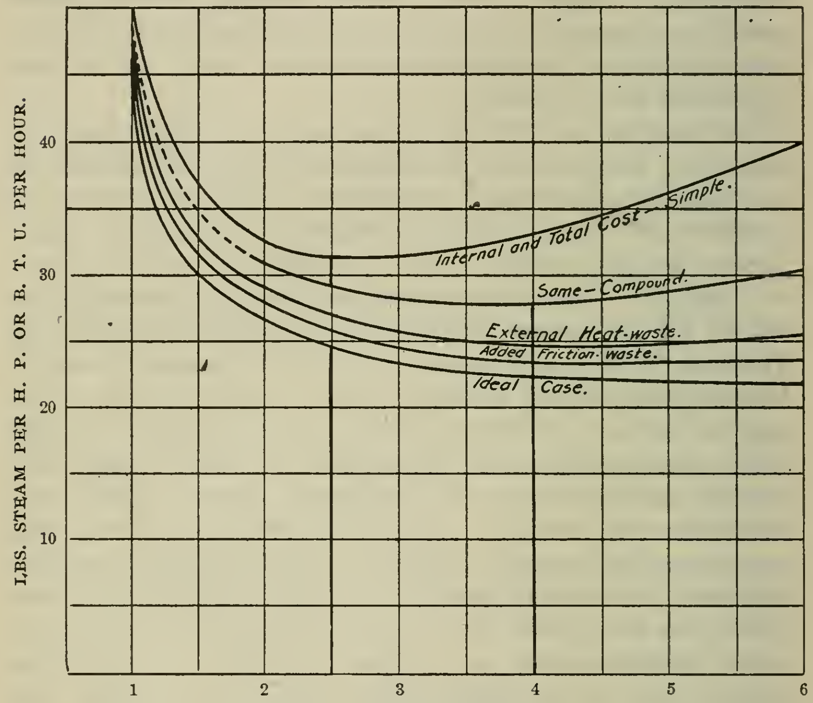

FIG. 2. LOCOMOTIVE.

SIMPLE ENGINE UNJACKETED. COMPOUND ENGINE JACKETED.

Steam at $p_1 = 120$ lbs. absolute; $p_3 = 20$.

Comparing the range of competitive operation, it is seen that, in these particular cases, the compound competes with the simple throughout the range from the ratio 4 to some point beyond our maximum limit on the diagram; that the triple-expansion competes with the compound from $r = 5·5$, and with the simple between 3·5 and the maximum; and that the quadruple similarly competes with the simple between 3 and the limit, with the triple between 5 and the extreme, and with the compound between 3·75 and 20 or more. It is assumed, in each comparison, that the basis of the competition is the duty, or the steam required per horse-power per hour. The simple engine competes, at its best ratio, with the compound and other engines only when the latter are working at abnormally low ratios of expansion, and each multiple-cylinder machine shows superiority over the preceding in our list at expansions which are always less than the best ratios of the simpler engine. These comparisons, however, obviously may result very differently when the complication introduced with the multiple-cylinder engine throws up the lines representing friction and external wastes to such height as to make the loss of energy in these directions exceed the gain by reduced internal wastes, and thus carries the upper line of the representative diagram for the latter above the line of total cost for the simpler machine with which it is compared. Very different and often very disappointing and unexpected results may thus follow where the engines are not suitably adapted to their working conditions, or when they are unskilfully designed and proportioned.

In all cases, whatever the type of engine, it is likely to be found that the best results are only to be secured when the extra thermo-dynamic wastes of the machine are intelligently treated and made as small as practicable. It is in this direction that the indications are that the greatest advances are to be made in the immediate future of the history of the steam engine.

Specific Applications of the principles illustrated in the general case just presented will be easily effected where the data are available. For example, let figure 2 represent the distribution of useful energies and wastes in the case of a locomotive. The thermo-dynamic case is computed, as per Rankine and as in the earlier work of the author.* The steam consumption is found by experiment to be approximately measured by $w = 45 / \sqrt{r}$. This quantity is increased, when the friction of the engine is taken into account by about ten per cent. at ordinary expansions, and the external heat wastes add a very nearly equal amount; both these wastes, however, being found by experience to be variable slightly with varying power and to be somewhat less as an absolute amount and greater relatively with decreasing expansion. Friction is taken as six per cent. of the full power, at full stroke, heat waste as 0·5 B. T. U. per square foot per hour per degree difference of temperature between the internal and the external temperatures. Adding the internal wastes by condensation, leakage, clearance and wire-drawing, following Clark for the first-mentioned up to the middle of our range and later practice beyond, we obtain the upper curve and find our profitable expansion restricted to about $r = 2·5$; which accords with general experience from Clark's earliest work to the present time. But, should these last wastes be decreased by compounding or superheating, as is known to be practicable, to one-half their present amount, the limit-curve would fall to the second line, and the allowable ratio of expansion for highest duty and lowest consumption of fuel in regular work would fall correspondingly, giving a higher ratio $r = 4$ or 5, and a consumption of fuel or of steam more nearly three than four, and twenty-five than thirty-two, as the first set of figures would probably read. In other words, the gain would be not far from twenty-five per cent. Both the first and last results have been bettered by engines of each type; but the relative standing of the two should be very much as here indicated.

The two cases above studied are those of engines working under what is generally considered high steam-pressure. The following will illustrate the operation of the older type of machine, simple, unjacketed, condensing, with steam at sixty pounds absolute, forty-five by gauge, nearly. It is the engine employed for marine work a generation ago and of which numerous examples survive. In the figure, the lower curve, as before, represents the ideal thermo-dynamic case. The consumption of steam, assuming the temperature of the hot well and feed such that 2·5 pounds would be demanded per hour per horse-power for efficiency unity, is

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* Rankine, p. 192, et seq.; Thurston's Manual, vol. i, arts. 116, 117, and especially 123, 137.

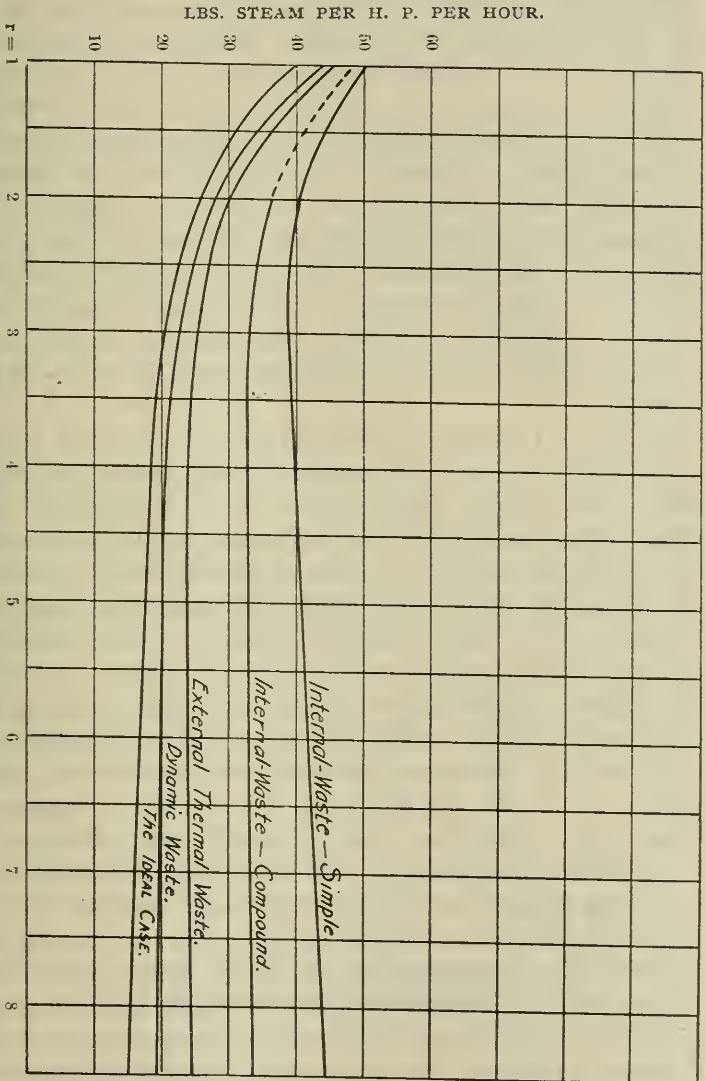

Fig. 3.—Condensing Engine.

SIMPLE UNJACKETED. COMPOUND JACKETED.

Steam at p_1 = 60 lbs. absolute; p_3 = 4.

again about $w = 40 / \sqrt{r}$, and varies between 40 at full stroke to 20 at 3·5 $\sqrt{4}$ expansions and 15 at $r = 8$. Internal and external wastes are computed as before, and the internal wastes are taken as found by Isherwood for the average marine engine of his time. Here the dynamic wastes appear to be a heavier proportional tax on the machine than in the case of the locomotive or in that of the high-pressure condensing engine, and limit the gain by increasing expansion to about $r = 2·5$ or $r = 2·75$. By both compounding and jacketing, we convert the engine into the representative multiple-cylinder machine of Hirn's experiments and of Hallauer, and at once find it possible to gain by carrying expansion to a new maximum at $r = 6$ or $r = 7$, while the efficiency becomes a nearly constant quantity over a very wide range—from three to eight or more.

In both these last two cases, the compound shows its superiority in range of profitable expansion, as compared with the simple engine, and it is seen more clearly than before how great are the losses in the simple engine with variable loads, on either side the best adjustment of cut-off and load for the individual machine, and the enhanced gain, for such cases, obtainable by the substitution of the condensing multiple-cylinder engine. The same superiority is obtainable by the adoption of the principle of "compounding" with the non-condensing engine, especially at high pressures, *provided* the limit is not passed at which the expansion line falls below the atmospheric, beyond which limit the machine rapidly loses efficiency.

Financial Conditions, as was shown by Rankine, as early as the middle of the nineteenth century, are the final limiting considerations in adjusting the power of an engine and its method of expansion to secure the best possible results in any given location and in stated conditions of the market for labor and material. Were it the purpose of this paper, it would be easy to introduce them into the diagrams which have been given to illustrate purely physical conditions; but these may perhaps be treated more conveniently by the methods earlier developed by the writer, and in which all these obstructive elements and their varying effects are so treated as to permit both graphical and analytical deduction of the maximum commercial efficiencies—of which there are several—and the solution of many interesting as well as of the essential problems designated by the writer, respectively, as the "designer's problems" and the "owner's problems."*

It is easy, however, to see that if the vertical scale of our diagrams were, as it might perfectly well be made, one of dollars instead of weight of steam, we might superpose upon the series of curves, constituting each, another, which should represent the varying costs of power external to the engine and the boiler plant, those costs which measure the annual value of capital invested and expenses incurred, apart from the internal costs of production of the power; such as, for example, in the former class, the interest on costs of engine, boiler, buildings, etc., and on the same scale which would measure the costs of the steam-supply already treated of. Referring to the first set of curves, assume the next to the upper line to represent these "internal" costs, and the upper curve to measure the "external" expenses, it is here seen that, as is the known fact, the latter being an increasing relative magnitude, the departure of the pair of curves from each other with increasing expansion, indicates that these new considerations dictate still further restriction of the ratio of expansion and still further narrow the range of nearly constant economy. As is elsewhere shown by the writer, this restriction is often more effective than even the enormous influence of internal wastes has been seen to prove. Where the designer seeks to ascertain what adjustment will give him the best work in proportioning an engine of either class to perform a specified amount of work, he often finds it necessary to adopt a ratio of expansion not exceeding two-thirds that dictated by the solution of the problem which it is the principal purpose of this paper to study; and when he again endeavors to ascertain to what power his client may drive up engine and boiler to obtain highest pecuniary returns from a "plant" already established and adapted to a specified original power—it being found that more power may be usefully employed or sold—he again finds that he may profitably restrict the ratio of expansion by perhaps another twenty-five per cent., and obtain large or at least fair profits on the new investment, notwithstanding the facts that the power added costs him more per unit than the original amount supplied by an engine precisely adapted to that rating, and that the new total power might be still more profitably produced by a new plant of proper rating and adjustment.

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* Manual, vol. i, chap. vii; vol. ii, chap. viii.

NEW CELLULOSE DERIVATIVES.*

By Clayton Beadle.

Nearly two years ago, my colleagues, Messrs. C. F. Cross and E. J. Bevan, and I, when working on the behavior of "mercerized" cellulose towards various reagents, discovered a new class of soluble cellulose derivatives. The ultimate products obtained from these promised to be of so much value and interest that we followed the work up with the greatest possible speed, one of us devoting his whole time to the prosecution of this work. It has resulted in the production of a large range of products, which we have every reason to believe are of great value. Mr. Arthur D. Little has been connected with us in working out the various developments over here. The results obtained by him, we believe, have largely added to the value and scope of our process. We published a brief account (*Chem. Soc. J.*, 1893, 837) of our early work on these compounds and indicated their probable line of developments. (*Soc. Chem. Ind. J.*, June 30, 1893.) After nine months' further work we are encouraged in the belief that the predictions we then made are on the eve of fulfilment.

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*Read at the stated meeting of the Franklin Institute, April 17, 1894.

"MERCERIZED" CELLULOSE.

The action of strong solutions of caustic soda upon cellulose has been the subject of study for many years; but the susceptibility of cellulose to interact when so treated has only recently claimed attention. When cellulose (*e. g.*, cotton-wool) is treated with a solution of caustic soda containing fifteen per cent. NaOH the fibres are seen under the microscope to swell up and increase enormously in diameter, undergoing all sorts of contortions and twistings. The characteristic markings of the fibres are very much intensified, which affords a means of identification. The cell-wall absorbs within itself a considerable quantity of the solution. When this mass is washed with water, the soda is entirely removed. If pure cellulose be used, the weight obtained is somewhat greater than that of the cellulose taken. This effect has long been known as "mercerization."

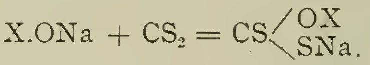
Mercer, the first to study this, believed it to be due to a combination between the alkali and the cellulose in the ratio of $C_{12}H_{20}O_{10}$: 2 NaOH. On repeated treatment with alcohol, Gladstone has shown that the cellulose retains the soda in the ratio $C_{12}H_{20}O_{10}$: NaOH. The question whether "mercerization" is the result of a chemical union between the cellulose and soda, or the absorption of the soda, by the cellulose, resulting in the hydration and gelatinization of the latter, to form a colloid modification, must be left at present unanswered. The soda solution entering *en masse* into the cell-wall, and its easy removal by washing, would lead us to the latter conclusion; but for various reasons which we shall see hereafter it would appear that some sort of a union between the soda and cellulose takes place. Mercerized cellulose when washed and dried is found to correspond with the formula $C_{12}H_{20}O_{10}, H_2O$. The hygroscopic moisture is found to have increased from 6·5 per cent. (the normal figure for cotton-cellulose) to ten per cent. In common with most cellulose-hydrates it gives the starch reaction with iodine. This is beautifully demonstrated by placing drops of caustic soda solution of different strengths on Swedish filter-paper; after a few minutes, washing the same until free from soda, it is dipped into iodine solution. The portion treated with caustic soda will be turned deep blue if the soda is up to "mercerizing strength." If the soda used is below this strength, a circular fringe of blue will be developed on the edge of the spot, where the water has evaporated and so concentrated the soda. This test gives us a means of determining whether the right "degree of mercerization" has been reached.

CELLULOSE-BENZOATES.

About three years ago we began to study the reactions of cellulose in presence of strong alkaline solution and obtained cellulose-benzoates by shaking with benzoyl-chloride. The yields and analyses showed variations between the di- and tetra-benzoate according to conditions of working. The yield of benzoate is limited, as might be supposed, by the "degree of mercerization." By dissolving certain hydrated modifications of cellulose in caustic soda, products of a uniform composition were obtained giving a higher yield of benzoate (*vide supra*). The activity of cellulose in this direction led us to study its behavior in regard to the vapor of carbon bisulphide.

CELLULOSE THIOSULPHOCARBONATES.

We found that when so-called "alkali-cellulose" is treated with carbon bisulphide vapor, at the end of three hours the mass will have changed to a deep golden yellow. This, when treated with water, swells up to a gelatinous mass and finally dissolves, forming a very viscous solution, about the color of treacle. The reaction that takes place may be expressed as follows :



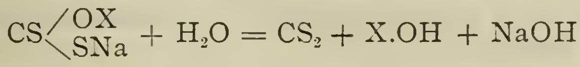
$$\mathrm{X.ONa} + \mathrm{CS_2} = \mathrm{CS}\begin{matrix}\diagup \mathrm{OX} \\ \diagdown \mathrm{SNa}\end{matrix}.$$

Alkali-Cellulose. Cellulose Xanthate.

where X represents the reacting unit of cellulose. We have then cellulose-xanthate formed, which is soluble in water, with the formation of the solutions as above described.

COAGULATION.

This solution lasts only for a limited time. In a few days it is found to have set to a solid coagulum which is no longer soluble in water. The action which takes place is simply a reversal of the above, or a dissociation of the xanthate, which is readily brought about in presence of water.



$$\mathrm{CS}\left\langle\begin{matrix}\mathrm{OX}\\ \mathrm{SNa}\end{matrix}\right. + \mathrm{H_2O} = \mathrm{CS_2} + \mathrm{X.OH} + \mathrm{NaOH}$$

Cellulose Xanthate. Cellulose.

The tendency of the solution to coagulate is conditioned by the amount of water present. Dilution, as might well be supposed, has been found to favor dissociation. The life of the solution is then greatest when the minimum quantity of water is used to bring the xanthate into solution. The color of the solution is chiefly due to the presence of thiocarbonate of soda, which is formed from some of the CS_2 and NaOH splitting off by gradual dissociation.

PROPERTIES OF THE SOLUTION.

Sulphuric and most mineral acids immediately precipitate the cellulose with the evolution of sulphuretted hydrogen. Acetic and many weak organic acids evolve sulphuretted hydrogen without precipitation of cellulose, the solution becoming nearly white and colorless, but much more liable to rapid coagulation. Bisulphite of soda or sulphurous acid decolorizes the solution without the evolution of sulphuretted hydrogen if carefully added. Zinc sulphate or chloride precipitates the zinc salt in horny flakes, which can be washed and easily redissolved in weak soda. Alcohol or brine precipitates the cellulose as thiocarbonate, which can be washed free from by-products and dissolved in water.

VISCOSITY OF SOLUTION.

This solution is very viscous, and very readily undergoes coagulation. The viscosity of the crude solution depends upon many conditions. It is possible to prepare two solutions from the same cellulose, one containing five per cent. and the other twenty per cent. of the same viscosity. If the cellulose has been treated with caustic soda some weeks before treatment with CS_2, the viscosity of the solution is very much reduced. Raising the temperature of the alkali-cellulose has the same effect. A solution of greatest viscosity is got by treating with CS_2 immediately after mercerizing. This gives us, when cotton is used in a seven per cent. solution, a viscosity equal to glycerine, measured by rate of flow.

SPECIFIC GRAVITY OF SOLUTION.

The determination of the specific gravity of solutions of various strengths is not very satisfactory, but it clearly indicates that the specific gravity decreases with decreased viscosity, due to increased age of alkali-cellulose.

EFFECT OF TEMPERATURE.

Increased temperature shortens the life of the solution by inducing coagulation. A solution that would last forty days at 35° F. would coagulate in twenty-five days at 47° F., or in six days at 65° F. When a solution is spread on the surface of glass and exposed to a temperature of about 250° F. the coagulation takes only a few minutes. This, when washed free from by-products, comes off the surface as a transparent film.

EFFECT OF MASS.

Mass has a great influence on coagulation; a small sample of thirty grams coagulates much sooner than a 400 pound lot of the same solution when both are kept at the same temperature.

AIR AND CARBONIC ACID.

Coagulation is induced by exposure to the air, probably due to the presence of carbonic acid, which is found to aid dissociation of the cellulose thiocarbonate, by forming sodium carbonate and liberating CS_2.

PROPERTIES OF COAGULUM.

A solution when once coagulated, although it retains the water required for its solution, is no longer soluble. If a coagulum contains much under ten per cent. of cellulose it will contract on itself, retaining the form in which it was cast and separating from the water and soluble by-products until it contains about ten per cent. of cellulose and ninety per cent. of water. On the other hand, if the coagulum contains a high percentage of cellulose it will expand and take up water. This coagulum will not dehydrate by treatment with alcohol. At this point it remains in a state of equilibrium so long as it is kept immersed in water. When the washed coagulum is taken out of the water and placed in air, by a gradual process of integration, the mass gradually contracts on itself until the whole of the water is eliminated. The resulting material is a hard, compact, horny substance, having a specific gravity of 1·5.

DECOLORIZED ACETIC ACID SOLUTION.

The crude thiocarbonate solution, when decolorized by the addition of suitable reagents, shows some marked peculiarities. When acetic acid is added, sufficient to render the solution just acid, on standing for some time the solution will have increased in viscosity and developed a marked alkaline reaction. The acetic acid decomposes the sodium thiocarbonate present in the solution, and, as dissociation proceeds, CS_2 is given off and caustic soda formed. If a non-viscous solution has been used, the viscous form can be induced by this method. The solutions coagulate a few hours after the addition of the acids unless kept very cool, and are more stable in dilute than in strong solution. A fresh coagulum from a strong solution can be rendered soluble by the addition of water and agitation, and the life can be extended for a considerable time by adding successive quantities of water at regular intervals and agitating. Alum may be used in place of acetic acid.

EFFECT OF SULPHUROUS ACID ON SOLUTION.

When sulphurous acid solution or sodium bisulphite is used in place of the above, the behavior is somewhat different. The sulphur compounds are, for the most part, converted into thiosulphate, and we have a more permanent solution. The influence of mass is here very much marked.

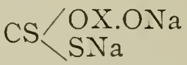
On placing the solution in tubes of different diameters, the smallest coagulates first, and so on, in order of diameter. The life of the solution is about thirty hours in small quantities, but it can be kept for six days in large quantities at the same temperature. It is more stable in dilute solution and the fresh coagulum is readily dissolved by ammonia.

PRODUCTS PURIFIED BY ALCOHOL OR BRINE.

The product got by purification with alcohol or brine is found on analysis to contain less sulphur and soda than the crude material, and by repeated treatment these may be got down to one-tenth their former quantity, but are found to bear about the same ratio to each other. As the S and Na_2O diminish, the solutions are found to be more viscous and less stable. It appears that the reacting unit of cellulose is not constant, and that the molecule may be at least $4(C_{12}H_{20}O_{10})$. The fact that two parts of cellulose in 1,000 parts of water, as a decolorized solution, will coagulate without change of volume, leads us to believe that the molecular weight of this cellulose is very high.

BENZOYL-CHLORIDE REACTION.

When a crude solution is treated with benzoyl-chloride, the cellulose is eliminated as a cellulose-benzoate. In view of this fact, we may be right in ascribing the following formula to the compound :



$$CS\begin{cases}OX.ONa\\SNa\end{cases}$$

X representing a cellulose residue of variable molecular weight and reacting as an alkali cellulose.

COMMERCIAL PRODUCTION.

In preparing large quantities of this cellulose compound, we take a moist, disintegrated cellulose and incorporate it with strong caustic soda solution by agitation under considerable pressure. The cellulose, when acted upon by the soda, swells up and absorbs all the solution, becoming flaky. This is passed through a sieve in order that it may be of uniform density and occupy as much bulk as possible.

This process takes about thirty minutes, and one hundred and fifty pounds of mercerized product is obtained at each mixing. One cubic foot of the material ready for treatment with the CS_2 weighs about fifteen pounds. This is brought in contact with CS_2 vapor when the mass has been carefully raised to 80° F. and kept in agitation. The reaction develops enough heat to raise the temperature to 105° F., when at the end of one hour the reaction is complete. The material still retains its former structure, but has changed in color to a golden yellow. It is discharged into, and carefully mixed with, its own volume of water. In seven hours the mass has become a homogeneous stiff dough. To obtain a clear solution from this, it is passed, together with its own weight of water, through a centrifugal pump, and to free it from mechanical impurities it is passed under pressure through a filtering medium. The amount of caustic soda required is expressed in its simplest terms by the ratio $C_6H_{10}O_5 : 2\ NaOH$. The proportion of CS_2 used is expressed by the ratio $CS_2 : 2\ NaOH$.

The most favorable conditions for the interaction are:

$$C_{12}H_{20}O_{10} : 2\ Na_2O : 2\ CS_2 : 35\ H_2O.$$

THE PRODUCTION OF CONTINUOUS FILMS.

When dehydrating agents, such as brine or alcohol, act on the cellulose thiocarbonate solution, the effect produced is dependent upon the constitution of the solution. Thus, if a fresh solution is used and brine added, the flocculent precipitate obtained is entirely redissolved in water. If the solution has been made some days and approaching the point of coagulation, the precipitate so formed is during precipitation converted into insoluble cellulose. If some of this solution is spread as a varnish on a glass plate, and immersed in brine, the cellulose can in a few seconds be stripped off the surface in the form of a film. We endeavored to take advantage of this for the production of continuous films, and after erecting six machines, each of which was a step in advance of the last, we devised a machine which produces and reels a film in a continuous web. The thick solution, which has been kept till on the point of coagulation, is spread on the surface of a revolving cylinder half immersed in a bath of brine. The solution is spread by means of an adjustable doctor, attached to side deckels which regulate the width of the film required. The film as it leaves the brine is stripped from the cylinder and passed through a series of vats for washing, decoloring, dyeing and finishing. It can be dried by passage over steam cylinders and reeled. The film when in the web, before passing on to the drying cylinders, can be grained or stamped by rolls carrying designs in imitation of any surface. Cellulose films prepared by this method have an affinity for many aniline colors not shared by any other form of cellulose. Its power of absorption of various substances when in the half-finished state enables us to give to the finished product a large range of properties.

It becomes dyed so readily with some aniline colors without a mordant, that the operation can be done in the web as it passes over the machine. When dried and finished it becomes resistant and loses considerably its chemical activity.

COMMERCIAL PRODUCTION OF THICK FILMS.

(1) From crude coagulum. In order to prepare thicker films the solid coagulum is cut up into pieces of any desired thickness. These are washed to free them from by-products, and treated for some time under pressure, and calendered. By this means we are able to get a large range of products. Calendering has a marvellous effect on the films, if they are not thoroughly dehydrated. The material of the film flows under great pressure, increasing the area and decreasing the thickness of the film, and the annealing it gets very much improves its texture and strength. We have recently found it possible to forego the process of washing out the by-products, giving us films sufficiently pure for some purpose, by the following process:

(2) From decolorized coagulum. To the crude thiocarbonate solution is added a weak solution of sulphurous acid, which has the effect of decolorizing the by-products

by converting them for the most part into sodium thiosulphate. The coagulum formed from this is a semi-opaque neutral jelly. This is cut up into pieces of the size required, and each piece is submitted to a process of annealing under pressure which results in the dehydration and separation of the cellulose from the by-products. It has lately been found possible to pulverize the solid decolorized coagulum and cause it to go together into compact sheets under pressure; also to force several sheets together into one solid compact sheet. We had failed with all other mixtures to obtain a pulverized substance that would go together under pressure, and had given it up thinking it could not be accomplished, when the above mixture was formed to answer. It is very difficult to explain this peculiar behavior of a cellulose coagulum, and why the various mixtures should behave so differently. We recognized that we are dealing with a compound in a state of very unstable molecular equilibrium and consequently very susceptible to all sorts of outside influences. The effect of pressure in promoting chemical change has recently been recognized. We think that we have here a marked instance of what pressure will do in effecting a molecular change. By changing the modes of attack on this coagulum various products are obtained, differing widely among themselves in their general properties. We have found it possible to stamp boxes direct from the coagulum, embossing and dehydrating them in one operation.

Films may also be produced by taking a continuous veneer from a revolving cylinder of the dehydrated substance.

INERTNESS OF THE DEHYDRATED PRODUCT.

This is well exemplified in its application to woven fabrics. Cotton and linen goods behave very differently in regard to their affinity for, and power of fixing, these cellulose derivatives. When gray linen is passed through a weak solution of cellulose thiocarbonate it is easily fixed by the film. It appears to penetrate the cell-wall and build itself up in the fibre. The cellulose so fixed is not removed by the various chemical treatments the cloth afterwards receives. The character of the solution used has a great effect on the finish of the cloth. It is possible to obtain a very marked difference in the feel by the addition of only two per cent., or to add to the cloth as much as twenty-five per cent. without making any marked difference. In all cases the cellulose derivative shows itself less acted upon by chemical treatment than the fibre of the cloth.

PROPERTIES AND CONSTITUTION.

Its inertness is shown also in its behavior with various reagents. Where it reacts it does so in a different way from that of cotton and linen cellulose. Its carbon percentage is somewhat lower and its weight is somewhat greater than the cotton cellulose from which it is prepared. The original molecule appears to have undergone hydration in the ratio $2C_{12}H_{20}O_{10}, H_2O$. The hygroscopic moisture varies from ten per cent. to fifteen per cent. according to the method used for its production. It is turned blue by iodine solution.

HYDRATION AND CONSTITUTION OF CELLULOSE.

It seems probable that in "mercerization" some of the OH groups are brought into play, rendering the molecule susceptible of attack by the carbon bisulphide; also that the OH groups play an important part in the molecular hydration. At the moment they are released by the dissociation of the thiocarbonate, the water present enters into a loose union with these groups, resulting in the formation of a coagulum which easily undergoes dehydration.

In a series of nitro-celluloses we prepared from cotton, of varying degrees of nitration, we found that the amount of moisture retained on exposure to air varied inversely as the yield. The moisture retained, then, varied directly as the OH groups left unsaturated. This led us to the conclusion that the moisture is some function of the OH groups. If, then, as we have reason to believe, in the formation of these cellulose derivatives certain other OH groups are brought into play, we should expect to find an increased attraction for water as above noted.

APPENDIX.

INDUSTRIAL APPLICATIONS OF CELLULOSE THIOCARBONATES AND PRODUCTS DERIVED THEREFROM.

By Arthur D. Little.

It was my good fortune to have the brilliant discoveries of my friends, Messrs. Cross, Bevan and Beadle, of London, communicated to me very shortly after their inception, and since then my time has been largely devoted to working out certain of the more obvious commercial applications of the cellulose thiocarbonate and the modified form of cellulose recovered through its decomposition.

Although in the early stages of the work numerous practical difficulties were naturally encountered, the development is at the present time going forward so rapidly that I cannot but feel that ultimately these discoveries will rank with that of Goodyear in the range and importance of their applications. Many fields in which these products will undoubtedly find place have already been entered upon, while almost daily new ones present themselves. Although the samples which we are able to show you to-night illustrate such diverse products, as thick, viscous solutions which replace glue; dense, hard masses which resemble ebonite; films so thin as to be almost intangible: artificial leather, floor tiles and boiler coverings—they are to be regarded only as the first outcroppings which show the general trend of the vein.

At the present time the various industrial applications of these materials, which have been sufficiently developed to permit the production of samples, may be conveniently grouped into six classes as follows: Applications of

(1) The crude solution.
(2) Dense cellulose in the mass.
(3) Films and sheets.
(4) Films and sheets formed on cloth backing.
(5) Porous cellulose.

(6) Various admixtures of cellulose and foreign substances, as untreated fibre or mineral matter.

In the production of almost all the samples here shown, the raw material used has been cellulose in the form known to paper-makers as soda fibre made from poplar wood; but as already pointed out by Mr. Beadle, any other cheap or convenient form of cellulose is equally available.

Taking up now in the order indicated above the different industrial applications to which these new products have already lent themselves, we have to consider:

(1) THE APPLICATIONS OF THE CRUDE SOLUTION.

(*a*) *Substitute for Glue.*—The viscosity and tenacity of the solution in water of the cellulose thiocarbonates, and the fact that the compounds upon drying and standing suffer spontaneous decomposition with recovery of the cellulose as an insoluble film, early suggested the use of the solution as a substitute for one of glue. A solution containing five per cent. of cellulose is much more viscous than a hot solution containing fifty per cent. of glue, and a ten per cent. solution is, under ordinary conditions, as heavy as can be worked to any advantage.

A one per cent. solution decolorized with sulphurous acid has been used in the commercial way for bill-posting, book-binding and the manufacture of three- and four-ply straw boards. No attempt has been made to wash out the salts, and in view of this fact it is noteworthy that there is an entire absence of odor in the finished product. The solution has been used in place of glue in binding a large number of books of all grades, from the cheapest to the most expensive. It will be noted upon inspection of the samples that all these books open perfectly flat at any page without straining or cracking the binding. No extended experiments have as yet been made looking to the use of this glue substitute in carpentry, but two pieces of maple, cemented with a ten per cent. solution on a joint of one inch area, have required a strain of over 500 pounds to separate them. This compares favorably with the best glue, while in cost there is a large balance in favor of the cellulose solution. The latter has the further advantage of being comparatively little affected by a very moist atmosphere.

(*b*) *Cloth Sizing.*—A large field of use for the decolorized solution is found in the treatment of cotton and linen cloth for the purpose of securing a permanent stiffening or sizing, which is of special value in case of such goods as would ordinarily be starched. The cloth is passed through the decolorized solution, the excess squeezed out by rollers, the cloth then dried and afterwards washed and bleached in the usual manner. By this treatment the threads and fibres are more or less bound and held together by an excessively thin film of cellulose and any degree of sizing or stiffening may be obtained. Starch, clay and other fillers may be mixed with the solution and are then carried into the body of the fabric and made a part of it. Cloth thus sized or loaded becomes soft and flexible in water so that it may be washed without difficulty but again becomes stiff when ironed. It is expected that such cloth will find a use in the manufacture of collars and cuffs, table-cloths, shirt-bosoms, muslins, etc.

(*c*) *Vehicle for Pigment Printing.*—An extension of the above application is found in our new method of pigment printing, which consists in mixing the pigment with the decolorized cellulose solution, then printing upon cloth in the usual manner, then drying and finally washing. The drying decomposes the cellulose compound and causes the modified cellulose to adhere to the fibres, while at the same time carrying with it and fixing upon them the pigments with which it has been mixed. The pigments are thus firmly held within the substance of the cloth.

(*d*) *Paper Sizing.*—The addition of alum to the very dilute solution of the cellulose thiocarbonate determines the precipitation of the cellulose in the amorphous flocculent condition. It thus becomes possible to precipitate the cellulose among the fibres in a paper engine after the ordinary manner of engine sizing and the precipitated cellulose not only sizes the paper but brings together and assists in the retention of the fine particles of clay or other filler which would otherwise be in large part lost.

(2) DENSE CELLULOSE IN THE MASS.

This may be formed by allowing the solution to revert or decompose spontaneously with separation of the cellulose as a jelly. The by-products of the decomposition are removed by washing and the cellulose then dries down to a dense mass of specific gravity 1·53. It has much the appearance of ebonite, takes a high polish and may be easily grained or colored in the mass. It is quite homogeneous and may be worked in any direction. It has a field for use as insulating material and in the manufacture of buttons, tool handles, small articles and turned goods generally.

(3) FILMS AND SHEETS.

These may be made either in the continuous way, as pointed out by Mr. Beadle, or by pouring the solution upon a glass plate with deckel edges to control the thickness of the film or sheet, and then drying the solution down and decomposing the compound, preferably by dry heat or steam, and afterward washing out the soluble inorganic by-products. In this condition the sheets take colors very readily, and with proper care in the treatment may be made nearly as clear as glass, as will appear upon inspection of some of the samples submitted. Among the uses to which the thinnest of these films have been already put may be named the glazing of binders' board, the production of photographic films, facing blotting paper and the like. Specially lustrous and durable glazed papers are prepared by rolling on to the paper one of these thin films. If the paper is of the proper tint, a very close imitation of vellum is produced for use in book-binding.

The applications of the heavier sheets ranging from $\frac{10}{1000}$ to $\frac{20}{1000}$ or more of an inch in thickness are especially numerous. They may be stamped into small wares like plates, trays, boxes, brush-backs, shoe-counters, inner soles, embossed signs, etc., or the sheets may be printed upon and stamped in almost any manner desired. Attractive covers for small books and pamphlets have been made.

(4) FILMS AND SHEETS ON CLOTH.

These are either formed directly upon the cloth or by rolling the wet film on to the cloth. Cloth faced in either way with the thinnest films is well adapted for curtain-cloth, book-binding and many other special uses. Cloth with a facing from $\frac{10}{1000}$ to $\frac{30}{1000}$ inch in thickness is valuable for many large uses. It may be caused to resemble morocco leather very closely and takes all the fine impression of the grain under a proper roll or die. It is especially well adapted to upholstery work, embossed hangings and interior decorations. The thicker sheets have proved themselves a handsome and durable floor covering.

(5) POROUS CELLULOSE.

By working the solution in such manner that the recovered cellulose has an open or porous structure, a new product of much beauty is obtained, which is especially adapted for fancy printing, embossed hangings, book-covers, fancy boxes, signs and small articles. It has been proposed to utilize this form of cellulose as a substitute for sponges, and there is no doubt that the structure of the sponge can be reproduced.

(6) MIXTURES OF CELLULOSE AND FOREIGN SUBSTANCES.

The solution lends itself very readily to admixture with such materials as ground wood, various fibres, clay and other mineral matter, and in each case the resulting mixture of recovered cellulose and the foreign ingredient possesses some novel and useful property. In this way we have prepared floor coverings which are either flexible like oil cloth or linoleum, or hard and rigid like tiles. Various forms of insulating material have been made, together with trunk boards, embossed panels, emery wheels and many other special articles.

The above list by no means completes the number of applications which we either have in mind or in the partially developed state, but will suffice to indicate some of the points at which these new compounds may fairly be expected to touch the arts and to justify to some extent the high estimate which I placed upon the importance of these discoveries to the industrial world. Their value and interest from the scientific standpoint have already been widely recognized.

THE HEATING AND VENTILATION OF LARGE BUILDINGS.*

By Alfred R. Wolff, M.E.

[*Concluded from p. 50.*]

It will be noted that these temperature stipulations vary from American practice in the following particulars:

(1) Our calculations, in this vicinity, are based, in general, on an external temperature of 0° F.

(2) We figure on heating our corridors, staircase halls, etc., to from 65° to 68° F.

(3) 70° F. is the desired temperature in stores and dwellings, though 68° F. appears to many of us pleasanter.

As a rule, Germans are disagreeably struck, on their visits to this country, with the higher temperatures of our homes and offices.

Presently a practical illustration of the method of using the coëfficients and diagram of heat transmission will be given; but, inasmuch as the same example can also serve the purposes of showing the method of determining the amount of air required for ventilation, and the amount of heat and of radiating surface to be provided to meet all conditions, it will be well to first call your attention to a few other facts in relation to heating and ventilation, which enter the problem.

The external air contains four parts of carbonic acid in

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* A Lecture delivered before the Franklin Institute.

10,000, and a room is considered properly ventilated when the proportion of carbonic acid present does not rise to above six, possibly eight parts in 10,000. It can readily be shown that to secure the standard of six parts in 10,000 means the addition of 3,000 cubic feet of fresh air per hour for each person in the room; to attain seven parts, the addition of 2,000 cubic feet; eight parts, the addition of 1,500 cubic feet. This air may have to be heated in the winter months, from zero degrees F. to, say, 68° F., and at times higher, if it is to be the means of taking care, in addition, of the heat transmission from the room.

Furthermore, it may be well to point out that the value of radiating surfaces is about as follows:

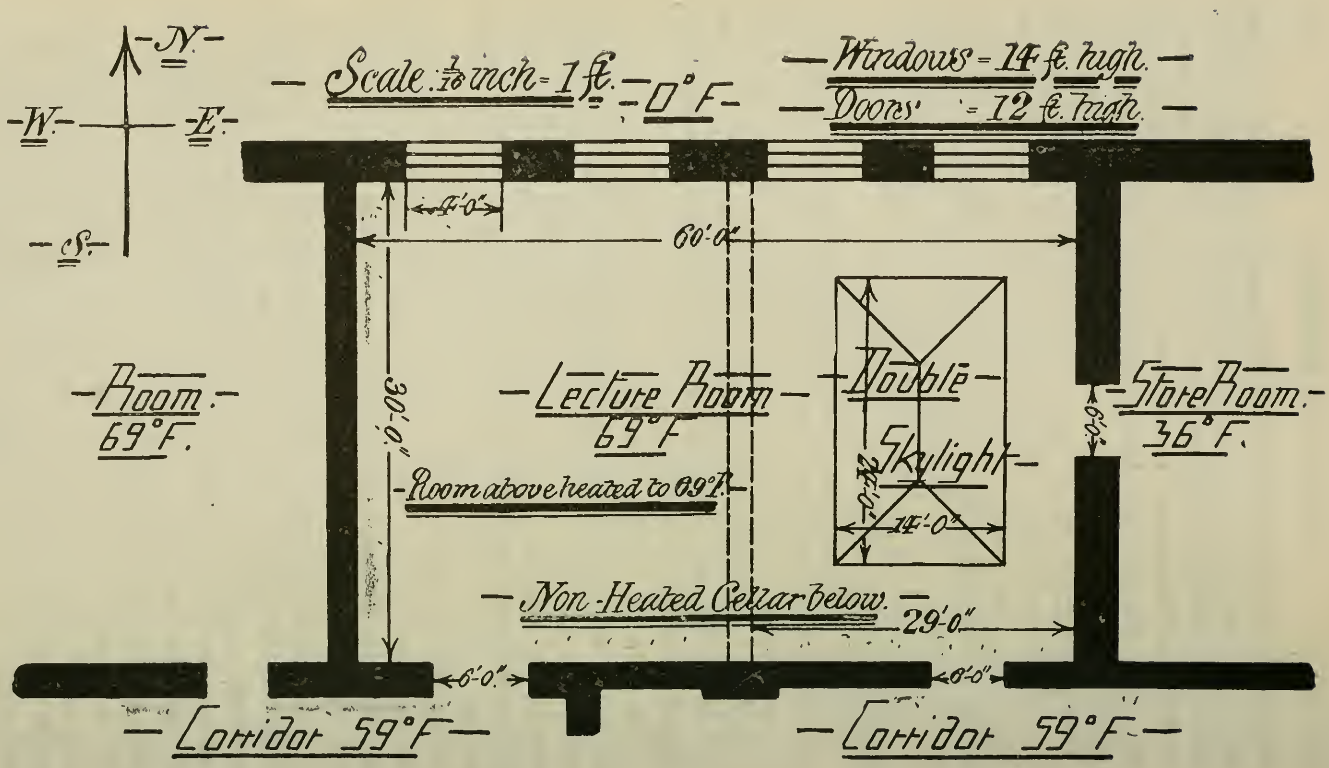
Ordinary bronzed cast-iron radiating surfaces, in American radiators (of Bundy or similar type), located in rooms, give out about 250 heat units per hour for each square foot of surface, with ordinary steam pressure, say three to five pounds per square inch, and about 0·6 of this amount with ordinary hot-water heating.

Non-painted radiating surfaces, of the ordinary "indirect" type (Climax or pin surfaces), give out about 400 heat units per hour for each square foot of heating surface, with ordinary steam pressure, say three to five pounds per square inch, and about 0·6 this amount with ordinary hot-water heating.

A person gives out about 400 heat units per hour; an ordinary gas burner about 4,800 heat units per hour; an incandescent electric (16 candle-power) light about 1,600 heat units per hour.

Now, for the practical illustration: Let us consider, as per accompanying sketch, a large room used. say, as a lecture room, 40 feet by 60 feet, and 20 feet high, situated as shown, and with exposures noted. Referring to our diagram and to coëfficients of heat transmission, and to data named above, we obtain the following:

If we assume that the lecture room must be heated to 69° F. in the daytime, when unoccupied, so as to be at this temperature when first persons arrive, there will be required, ventilation not being considered, and bronzed direct low


N
W
E
S
Scale: 1/16 inch = 1 ft.
0° F
Windows = 14 ft. high.
Doors = 12 ft. high.
4'0"
60'0"
30'0"
Room. 69° F.
Lecture Room 69° F
Double Skylight
24'0"
14'0"
Room above heated to 69° F.
Store Room. 36° F.
6'0"
Non-Heated Cellar below.
29'0"
6'0"
6'0"
Corridor 59° F
Corridor 59° F

pressure steam radiators in room being the heating media, about

$$\frac{113{,}550}{250} = \text{about } 455 \text{ square feet of radiating surface.}$$

(This gives a ratio of about 105 cubic feet of contents of room for each square foot of heating surface.)

If we assume that there are 160 persons in the lecture room, and we provide 2,500 cubic feet of fresh air per person per hour, we will supply 160 × 2,500 = 400,000 cubic feet of air per hour—

(*i. e.*, $\frac{400{,}000}{48{,}000}$ = over eight changes of contents of room per hour).

To heat this air from 0° F. to 69° F. will require 400,000 × 0·0189 × 69 = 521,640 thermal units per hour (0·0189 being the product of a weight of a cubic foot by the specific heat of air). Accordingly, there must be provided

$$\frac{521{,}640}{400} = 1{,}304$$

square feet of indirect surface, to heat the air required for ventilation in zero weather. If the room were to be warmed entirely indirectly, that is, by the air supplied to room (including the heat to be conveyed to cover loss by transmission through walls, etc.), there would have to be conveyed to the fresh air supply 521,640 + 113,550 = 635,190 heat units. This would imply the provision of an amount of indirect heating surface of the "Climax" type of

$$\frac{635{,}190}{400} = 1{,}589$$

square feet, and the fresh air entering the room would have to be at a temperature of about 84° F., viz.:

$$69^\circ + \frac{113{,}550}{400{,}000 \times 0{\cdot}0189} \text{ or } 69 + 15 = 84^\circ \text{ F.}$$

TABLE SHOWING HEAT UNITS TRANSMITTED FROM (AND TO BE CONVEYED TO) ROOM ON ACCOUNT OF HEAT TRANSMISSION THROUGH WALLS, CEILING, FLOOR, WINDOWS, ETC.

No.	Room.	Cubic Contents (in Cubic Feet).	t (Fahrenheit Degrees.)	$t - t_0$ (Fahrenheit Degrees).	Kind of Transmitting Surface.	Thickness of Wall (in Inches).	Calculation of Area of Transmitting Surface.	Square Feet of Surface.	$K (t - t_0)$	Thermal Units.	Supplementary Allowances.
	Lecture room.	48,000	69	69	Outside wall.	36″	63 × 22 — 448	938	9	8,442	10%
				69	Four windows (single).		4 × 8 × 14	448	72	32,256	10%
				33	Inside wall (storeroom).	36″	42 × 22 — 72	852	4	3,408	
				33	Door.		6 × 12	72	19	1,368	
				10	Inside wall (corridor).	24″	45 × 22 — 72	918	2	1,836	
				10	Door.		6 × 12	72	5	360	
				10	Inside wall (corridor).	36″	17 × 22 — 72	302	1	302	
				10	Door.		6 × 12	72	5	360	
				69	Roof.		32 × 42 — 336	1,008	10	10,080	
				69	Double skylight.		14 × 24	336	43	14,448	
				33	Floor.		62 × 42	2,604	4	10,416	

	83,276
North outside wall, 10%, ...	844
North outside windows. 10%, ...	3,226
	87,346
Exposed location and intermittent day or night use, 30%, ...	26,204
Total thermal units, ...	113,550

The above calculations do not, however, take into account that 160 persons in the lecture hall give out 160 × 400 = 64,000 thermal units per hour; and that, say, 50 electric lights give out 50 × 1,600 = 80,000 thermal units per hour; or, say, 50 gas lights, 50 × 4,800 = 240,000 thermal units per hour. The presence of 160 people and the gas lighting would diminish considerably the amount of heat required. Practically, it appears that the heat generated by the presence of 160 people, 64,000 heat units, and by 50 electric lights, 80,000 heat units, a total of 144,000 heat units, more than covers the amount of heat transmitted through walls, etc. Moreover, that if the 50 gas lights give out 240,000 thermal units per hour, the air supplied for ventilation must enter considerably below 69° F., or the room will be heated to an unbearably high temperature. If 400,000 cubic feet of fresh air per hour are supplied, and 240,000 thermal units per hour generated by the gas must be abstracted, it means that the air must, under these conditions, enter

$$\frac{240{,}000}{400{,}000 \times {\cdot}0189} =$$

about 32° less than 84°, or at about 52° F. Furthermore, the additional vitiation due to gas lighting would necessitate a much larger supply of fresh air than when the vitiation of the atmosphere by the people alone is considered, one gas light vitiating the air as much as five men. However, we need not consider these computations more in detail, our object being mainly to point out and illustrate the methods of analysis and calculation in such a case, and to show how readily the problems can be solved by the data herein given.

A few practical conclusions are at once apparent: That the amount of air required, and the temperature of the entering air, as well as the amount of heating surface to be called into play, will vary very greatly in the same room, not only with variations in external temperature, but with any given external temperature, according to the use, occupation, method of lighting, etc., of the room. Also, that the variations will often be so quick during a short period of use of room, especially in auditoriums, theatres, ballrooms, public dining-halls, etc., that it is important either to have automatic heat regulation, or a competent engineer, who constantly and closely watches the changes in temperature and modifies the operation of apparatus accordingly. Of course, a stable condition of audience, lighting, etc., once secured, the regulation is a comparatively simple matter (a fixed right condition of operation of apparatus then usually filling the need); but from the time of opening the hall until this stable condition is reached, conditions will vary so much that failure is sure to result with the otherwise best apparatus, unless it be designed to regulate its heat radiation, etc., automatically, to suit these varying conditions, or a most competent engineer, of good judgment, regulate the apparatus according to frequent thermometer readings or reports.

From the considerations already set forth, and others to be presented, it will readily be inferred that the almost general introduction of electric lighting with isolated generating plants in large buildings, has had a sensible effect on the solution of the heating and ventilating problem. On account of the economy secured, it has practically conditioned the use of exhaust steam for heating. It is an interesting fact that the quantity of steam required for heating and ventilating large buildings, notably club houses, colleges, theatres, halls, etc., equals closely the amount used independently for their electric lighting. Since electric light engines convert only about ten to fifteen per cent. of the heat of the steam with which they are supplied into mechanical energy, eighty-five to ninety per cent. of the heat is retained in the exhaust steam, available and just sufficient, as a rule, to meet the heating and ventilating needs of the building. This means practically that a boiler capacity ample for the heating and ventilating will take care, in addition, of the electric lighting of a large building, or *vice versa* ; and that, in the winter months, the electric lighting is secured at only a slightly increased fuel expense. It is this fact which makes it difficult for either city or district heating or electric lighting companies to supply steam or electricity, respectively, to large buildings. They cannot compete with the cheapness of generation of the composite system of electric lighting and exhaust steam heating of the isolated plant within the building. Of course, this composite system implies generally the additional wages of an extra fireman or engineer, but it can easily bear this additional expense, and still be decidedly on the winning side in competition with outside district companies. It is of importance to have the cylinder proportions of the electric light engines such that the desired power is developed with a back pressure as high as five pounds to the square inch ; for, in American practice, such pressure may be required for heating in the coldest weather. This back pressure, if originally figured on, is neither detrimental nor uneconomical, and I have not been able to recognize any advantages in the vacuum systems, except where the engines or the piping were proportioned incorrectly at the outset, or where the installation of the electric lighting plant, and the use of exhaust steam for heating, were afterthoughts. In those cases, the vacuum systems frequently perform a useful service.

Another way in which the introduction of electric lighting has affected the heating and ventilating problem is, as above already referred to, that the electric lights give out less heat and vitiate the atmosphere less than gas. Besides, there are no volatile products of combustion—representing vitiation and heat—to be taken off as far as practicable at the points of generation; nor must flicker of light, on account of air currents, be guarded against. The fact that a single gas light vitiates the air as much as do five persons, and that the electric light causes no vitiation whatever, materially affects the quantity of fresh air to be supplied to keep the atmosphere within a room at a proper standard of purity. Again, the fact that besides not dealing with obnoxious gases, no flicker of flames must be considered in electric lighting, renders it possible, when so desired, to bring in the fresh-air supply at the top of a room (either by wall registers or through perforated suspended ceilings) and to exhaust at the bottom, a reversal of the ordinary process, and one impracticable when gas lighting is resorted to.

While in my judgment the main problem in the proper ventilation of large buildings is to secure an adequate supply to, and removal of air from, the separate rooms, I would like to call your attention to a distinct and important advantage obtained by having the air enter through perforated ceilings at the top of the rooms, and exhausting at the bottom. At night, in a crowded assembly, when the electric lights aglow are giving out some heat, even though it be considerably less than gas lights would evolve, it is frequently found in practice, as the calculations of our example have already indicated should be the case, that, even in very cold weather, to keep the air within the room at a temperature of 68° F., the entering fresh air must be at a temperature considerably lower than 68°. At the recent opening of the new concert hall of the Mendelssohn Glee Club building, a room with scarcely any outside exposure, and practically dependent on an artificial air supply by means of a blower, it was found necessary, even while supplying over 3,000 cubic feet of fresh air per hour for each of the 1,000 persons in the audience, and with an external temperature of 40° F., to have as low a temperature as 52° F. for the entering air, to keep the hall at 68° F. Nor is this an unusual experience.

If the entire air supply enters by means of registers, or openings in or near the floor, it is very difficult, however large the openings, to obtain such a distribution and low velocity as will prevent the sensation of a cold draught when air is entering in large volume at a low temperature. It is a possibility, but usually it is impracticable structurally, to secure the required low velocity and uniform distribution. But if the air enters at the top, not only can a low velocity and uniform distribution be secured by means of large perforations in decorative designs of suspended ceilings, but a low velocity is of less importance, for the cooler air is heated in transit, and by the time it has reached the audience it has attained a temperature in the neighborhood of 68° F., and is no longer cooler than the air at exhaust where the people are congregated. If the hall is very high, it requires quite a powerful exhaust to ensure the air reaching the floor at such times as the entering air must be heated; but this is a detail readily solved in practice. In the main auditorium of the Carnegie Music Hall, with its seating capacity of over 3,000, the fresh, cooled or warmed air enters through perforations in the suspended ceiling, and travels with slow velocity a height of about eighty feet to exhaust openings in the floor risers, and an equable temperature is maintained under any external atmospheric conditions. In such a system it is specially important that the volume of air exhausted be less than the volume of fresh (warmed) air forced into the hall, so that the air within the room be under pressure; otherwise, external cold air will be drawn into the building through doors and windows, and may create objectionable draughts. But the desired conditions here briefly presented are readily attainable; and, especially in case of an enclosed room, the system of supply at ceiling and exhaust at floor level is the ideal one, when the room is lighted electrically, to secure pure air and moderate temperatures in crowded assemblies during the winter months.

In the summer time, many persons like to feel a decided current of cooled or cooler air, and thus it is often considered preferable to have the air enter at bottom and to exhaust at top of room. A reversible system may then be adopted to meet the conditions of comfort all year round.

In my own practice, when air enters and is exhausted through ducts in the walls, I have found it advantageous to have both top and bottom registers for each fresh-air flue, and top and bottom registers for each vent flue. In this way, the fresh air, when warmed, can enter at one and the same time through bottom and top register, with a corresponding desirable reduction in velocity, each flue having two outlets. When the air, in the winter months, on account of crowded assembly, must enter at a low temperature, the bottom register can be closed, and in the summer time, if a current of cold air is to be strongly perceptible, the top register can be closed. In general, when air enters through top registers, the exhaust should also be by means of the bottom registers of the vent ducts, and *vice versa*, and when air enters through both top and bottom registers, the exhaust should also be through top and bottom registers.

The selection of the special system of heating and ventilating to adopt in a particular building depends, of course, in addition to the considerations already set forth, and to similar ones of a physical and engineering nature, greatly on the structural possibilities; for, important as are the heating and ventilation, owners and architects are not as yet quite ready to sacrifice other useful and artistic features to the one which has been the topic of this lecture. The engineer, therefore, if he would not have the heating and ventilating needs neglected, should be quick to recognize the system to adopt which will insure success, and will, at the same time, not prove a nuisance to the specific architectural and artistic interests of the building. Frequently, such decision must be cast at a first inspection of the plans. Of course, there should be "give and take" in this matter on both sides, and the purely decorative and structural interests should occasionally yield a point too.

It is evident that the best result is achieved if the engineer who is to design the engineering equipment be consulted when the original architectural plans are drawn, and before these plans have crystallized into definite and unalterable shape; for thus, in harmony of co-operation, the best is accomplished by both the architect and the engineer, and the engineering equipment, including the heating and ventilation, proves satisfactory, without encroaching on the highest architectural, structural and artistic possibilities and success. In closing, it is a pleasure to record that at the present time some of the leading architects recognize the advantages of an early co-operation in these respects with the engineer.

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from p. 45.*]

In the preceding lectures, all the illustrations which have been used are commonly recognized as engineering works, though some are often classed as civil, and some as mechanical engineering. I have endeavored to show that the distinction is a purely artificial one; that the civil engineer who is to carry on responsible work, cannot get along without what is commonly called mechanical engineering; that the science of engineering is one, though very extensive in its range, and that the history of the development of engineering up to and in modern times is the history of the development of machinery, whereby we direct the great sources of power in Nature for the use and convenience of man. In this lecture, I propose to present to you a very brief view of the part that engineering work plays in what are commonly called the industries of the world. Of course, any presentation which I can make in an hour must be very incomplete, and I shall choose only a few illustrations, and leave them to serve as examples of a much larger number.

And first, before taking up any manufactures, I ought to say a few words about mining.

I suppose that, in the popular mind, mining operations have generally been intimately connected first with geology, second with chemistry, and but slightly with engineering; but, if we stop to examine the actual condition of things, we shall find, I think, that, whereas there are cases where the man who has charge of a mine, or of a metallurgical works, needs to give his own attention primarily to metallurgical, to chemical, or even to geological questions, and where engineering questions are a secondary consideration, the cases are more frequent where much the larger part of his attention needs to be devoted to the engineering questions that arise in the work.

Geology serves to locate the mine, and to inform him what he may reasonably expect to find within the bowels of the earth, and what is the precise location of the deposits, so that he may know what excavations to make to reach them. It teaches him also the nature of the neighboring layers, and the difficulties he is liable to encounter in consequence of the characteristics of these materials; but all the exploration is largely completed before the mine is opened, or, at least, it is usually finished for any portion before the works are commenced on that portion, so that the amount of geological work to be done during the operation of the mine is generally not large.

Chemistry tells him the composition of his ores and of his product, and hence gives him the means of determining how to mix and how to treat them, but any one mine is dealing with one kind of ore, and any one metallurgical works is conducting a certain special kind of operations, and, therefore, the chemical work required in connection with them is limited to certain narrow lines. The result is that, after the works have been running for some time, the chemical work, while it requires careful attention, is, nevertheless, largely a matter of routine: to carry it out are required men well drilled in this routine, and it is not necessary that they should be expert chemists, for, if a problem occasionally arises which is outside of the routine, and of sufficient consequence to warrant it, an expert chemist can be employed to solve it.

When we come to the case of metallurgical works, of course the man who is to manage them must have the necessary knowledge of metallurgy—of that kind, at any rate—or else he does not know his business, and he must devote whatever time and thought is necessary to all the metallurgical questions that arise which are not matters of routine, for those that are can be performed by men skilled in the special work, the manager only exercising enough supervision to see that these matters proceed correctly. When this is done, the problems that ought to engross the larger part of his time will depend upon the nature of the works. In some of them metallurgical problems will absorb more of his time than engineering, but in the greater number of such works the engineering problems will demand a larger part of his time and thought than the metallurgical, if he is to run the works with the best results.

Now, in the case of the engineering work, new problems are constantly to be solved, new emergencies are constantly to be met, for the mine must be kept running both economically and efficiently if the work is to be properly done; and if the works are large the engineering work assumes very large proportions. Some of it can be done by the manager personally, but a very large amount he must delegate to assistants, and these assistants must understand engineering.

In order to make plain how large an amount of such work has to be performed, I might say that in the case of a mine of any sort, unless it is very small, there is water that must be removed; hence, there must be machinery for pumping; the material mined must be lifted out of the mine, and the miners and various supplies must be carried in and out of it; hence, hoisting machinery of some sort is needed; rock drills must be used, and these are driven by compressed air; hence, air compressors, and suitable engines to drive them; the men must be furnished with fresh air and the foul air must be removed; hence, some sort of ventilation must be provided. All this is necessary in any mine, besides timbering or walling the shafts and certain galleries. Then when the ore has been hoisted it must be broken up and prepared in various ways before it is ready for the furnace, and in many cases the works for preparing it—commonly called the mill—are not far from the mine.

Confining our attention first to the mine itself, we find, in regard to the pumping, all sorts of methods in operation, some very wasteful, and others varying in economy in every conceivable degree, according to the amount of engineering knowledge, and the judgment of the mine engineer. Thus, he may use direct-acting pumps at the bottom of the shaft, and at intervals along it, but the engineer knows that these are very wasteful of steam, and hence of coal; or he may bring to bear his engineering knowledge, and put in whatever will be most economical under the circumstances, be it a triple or a compound engine to do the pumping. The details of the arrangements of pumps and pump rods, and their connection to the engine, are all matters that must be attended to. Then, in regard to hoists, there is great room for choice, and a good opportunity for the engineer to exercise his talents. Probably the most instructive example apropos to this phase of our subject is afforded by the hoist now being put in the Calumet and Hecla mine. This machine is to lift ten tons of ore at the rate of sixty feet per second, through a height of 6,000 feet. The engine is triple-expansion, with cylinders $20\frac{1}{8}$, $31\frac{3}{4}$ and 50 by 72-inch stroke.

At this mine many modern appliances have been introduced, among others three hoisting engines, which are triple-expansion, with cylinders 18, $27\frac{3}{4}$ and 48 by 90-inch stroke. In order not to interfere with the work of hoisting the ore, a separate engine is usually provided to run the man hoist, which may be the regular man engine, or may be a car drawn by another hoisting engine. Then comes the choice of compressors and engines to run them, their erection and operation; then the means of ventilation, whether by natural draught or by an exhaust fan.

All this, of itself, if the mine is of any considerable magnitude, means the establishing of a large plant of machinery, and hence all the engineering work and all the engineering features necessarily involved in the erection and operation of such a plant, besides the engineering work that relates particularly to the special machinery in use and the special work to be accomplished by it. There must be, of course, a suitable boiler house and chimney, and suitable boilers must be erected and operated with whatever adjuncts, as economizers, etc., it is thought best to use, the conditions here being exactly the same as they are in the case of any boiler plant, and hence, engineering questions. Then the principle which directs the engineer to concentrate his power in one place, as far as possible, and hence to use one large and economical engine instead of several small and wasteful ones, applies here as it does to any power plant. How far this concentration can be carried must depend upon a consideration of the special conditions of the work; and all this involves, of course, a consideration of the arrangement of the works and of the system of power transmission. Of course, the arrangement of the power plant will probably be affected by the manner of getting the power from the engine to the pump rods or man engine rods, or rope drive, etc., that carry the power to the shaft.

In all these works, in the erection of the buildings, in putting up the machinery, etc., as well as in making suitable constructions to hold it, and in timbering or walling the mine, maintaining the works in serviceable condition, etc., questions of strength of materials are constantly coming up.

Then, again, the engineer must consider the means of handling the ore as it comes from the mine, and of transporting it to the place where it is next required. Then, if it is to go to the mill, it must be carried there, or, if it is to go to a distance, must be loaded into cars. Of course the engineer will take advantage of the force of gravity whenever he can do so, for that costs comparatively little.

Next, as to the mill. Here the nature of the machinery will depend, of course, upon the particular kind of ore being treated.

We have first the ore dressing, and this involves the exercise of a very large amount of engineering. In certain cases the crushing is done by a stamp mill, in others by crushing machines or crushing rolls. Then come the arrangements for sorting the coarse from the fine, for separating the part which contains valuable material from that which does not, sometimes by gravity, sometimes by amalgamation, sometimes by magnetism, etc. Then, if the mine is large, the waste material must be removed, which is done by means of lifting or transporting apparatus, as, for example, the sand wheel.

Moreover, in any process of concentrating, a large amount of water will be needed, besides which it is also necessary for the boilers and for other purposes. Hence it becomes necessary to find a suitable water supply, and to set up the pumping engines required, etc.; in short, to establish a water supply, and finally, the waste water must be disposed of. Now, these engineering questions are everyday matters, and wastefulness or inefficiency here means expenditure with no return, hence all the coal that can be saved, all the labor that can be saved, all the saving that can be made by avoiding the doing of useless work, all the saving of unnecessary handling, will all show their influence in the dividends of the stockholders and in the successful operation of the mine just as truly as will the adoption of the proper treatment of the ore instead of an improper one. Of course, in any particular case, it becomes a question whether we will put in the best machinery, and thus economize in the running expenses, with, however, a larger first cost; or whether we will save on first cost at the expense of economy later on. Usually, if the owner lacks confidence in the amount of the ore in the mine, he will be wise to save on first cost. But if he knows that the mine will succeed, his best course is to put in the most economical machinery, notwithstanding that it is more expensive at first.

Next in order come metallurgical works. Of course, the treatment of the materials by metallurgical processes which will produce the proper result is the primary purpose of the works; but these processes cannot be carried on without buildings, furnaces, steam or water plant, power transmitting machinery and apparatus, the erection and operation of all of which involve engineering questions which, if neglected by those who operate the works, are sure to result in disaster. As an example, suppose the owner of a blast furnace should insist on burning coal under his boilers instead of utilizing the waste heat from the furnace, this would simply be throwing away so much heat, and hence so much money. Now, when competition becomes sharp, the man who can make a saving in any way is the gainer; and if unsuitable or weak buildings, or unsuitable or weak machinery, or lack of economy in steam, are tolerated, or if care is not taken to save labor as far as possible, the neglect is sure to result in loss; and it is the fact that people are beginning to realize the truth of this statement that is causing the proprietors of such works to pay more and more attention to their engineering features, and to seek men who are familiar with the principles of engineering, instead of attempting to carry on the engineering portion of the work with the aid of men unfamiliar with these principles, and hence liable to make serious and costly mistakes.

Now, in regard to the metallurgical and chemical processes, there is always a certain portion at least of these that, after the works have been running some time, become largely matters of routine, varying only within certain narrow limits; and these, while they need careful attention and skill, can be delegated to a superintendent, whose business it is to attend to this part of the work.

There then remains that portion of the metallurgical and chemical work which is not reduced to a routine, and all the engineering work (which can never be reduced to a routine), to be attended to.

Now, the relative proportion of time and attention required by each of these for its proper conduct, will depend upon the nature of the works, but it is my belief that in the greater number of cases, more time and attention is required for the engineering if the works are to be run economically and efficiently: but be this as it may, in no case can this branch of the work be neglected without loss.

My time is so limited that I shall only present for your consideration one illustration of a metallurgical works.

The discoveries and inventions that have furnished us the means of making cast iron, wrought iron and steel on a large scale, and cheaply, have had an enormous influence upon the industrial progress of the world.

In the early part of this century wrought iron was not used as a structural material to any such extent as it has been in recent times, and it was not until about the middle of the century that it began to come into common use for beams, for columns, for boilers, for bridges, and for many parts of machinery. But when once introduced, it became the great structural material of the age, and has held its sway ever since, until now, when steel is rapidly displacing it for many uses.

So long as steel could be made from wrought iron only, as by the crucible process, it was altogether too expensive a material to use in construction, but the introduction of the Bessemer process, by which it is made directly from cast iron, so cheapened it that steel rails at once came into use; and since that time the development of this process, and also of the open hearth or Siemens-Martin process, where a regenerative furnace is used, and where the steel is made from a mixture of pig iron and scrap or ore and other ingredients, have so far improved, that now our boilers are made of steel, and steel beams, steel ties, steel shapes, steel shafts, and steel for most pieces of machinery, which heretofore have been made of wrought iron, are fast coming into use.

Now steel works may, and very commonly do buy their pig iron from some blast furnace works, and proceed to melt it in a cupola, and then, if they have a Bessemer plant, to make it into steel, or, if an open-hearth plant, to put it at once into the furnace. But at some of the larger works, both in America and abroad, they have a plant which includes the blast furnaces, and which, starting with the ore, makes it into cast iron, and then, without allowing the melted iron to cool, converts it into steel; then rolls it immediately into the finished form of rails and other commercial product. In other words, the iron is not allowed to grow cold from the time that the ore first enters the blast furnace until it has become a finished rail.

Such a plant as this is that of the Maryland Steel Co. These works have been quite recently built, and great care has been taken to introduce the most modern ideas and appliances throughout.

The ore used is foreign ore, brought to the works by water, and as it is unloaded from the boat it is loaded into cars having a hopper on the bottom, which can be opened to dump the load. There is a railroad track running up over a series of pockets or bins, and the loaded cars are run up on this track to the proper place and the ore is dumped into these pockets or bins. From the bottom of these bins shutes extend downwards nearly to the ground, and through these shutes the ore is delivered on the ground in such small quantities as may be required. The coal and other raw materials consumed by the works are treated in a similar manner, some of the bins being used for ore, some for coal and some for flux. The ore, the coal and the flux, in turn as they are required, are shovelled into small, narrow-gauge truck cars, which are run upon a platform scale and weighed, the amount on the truck being adjusted by adding or by taking off some of the load while the car is still on the scale. The truck is then run upon an elevator, and raised to the top of the blast furnace. There are two such elevators, side by side, one of which rises when the other descends, their weights balancing each other when they are not loaded.

There are four large blast furnaces. When one car, the bottom of which is so arranged that it can be opened to dump the materials, arrives at the top, it is run on a track to a point over the top of the furnace, but to one side of the center; the next load being dumped on the other side of the center, insures an even distribution. Two trucks go up at once on an elevator, and there is room for both on one track over the furnace. The bottoms of the cars are opened, and the materials are dumped around the edges of a cone-shaped cover. Then, when the charge in the furnace has sunk low enough, as determined by sticking a long poker through a small hole in the cover, the cone is lifted, and the charge drops down. The lifting of these covers is accomplished by gearing and chains, which, of course, requires some power to operate.

The boiler plant is large, and contains a number of large sectional boilers. The waste gases from the blast furnaces pass out through a flue which starts below the cone already described, and then are conveyed to the boiler house, where the necessary flues and dampers are so arranged that, by manipulating the latter, the hot gases can be conducted under any one, or under several of the boilers, or sent directly into the stack. These boilers furnish steam for all the purposes for which steam is used, *i. e.*, for running the large compound vertical engines which produce the blast, for running the pumps and air compressors, etc. Water is circulated around the furnace to keep it from becoming too hot.

The furnace is tapped at the bottom, and the melted iron runs out, and, if they are making pig iron, which they can do, they would let it run into the usual trenches on the ground, known as the sow and pigs, or, if it is to be made into a rail before it cools, it is run from the furnace into a ladle, which, with its charge, is carried on a truck drawn by a little locomotive to the Bessemer plant. Here the charge is poured into a large chamber or reservoir, called a mixer, which thus contains a store of melted cast iron to be drawn from as needed.

Near the mixer are some small cupolas, where some pigs are melted. A charge is now drawn off into a ladle, this charge being often a mixture of metal drawn from the mixer and from the cupola. This ladleful of metal is now poured into a Bessemer converter while it is on its side. Then the blast is turned on and it is then placed in the erect position, and at once we see flames shoot out of it. The flames at first burn off the silicon; when this is burned out, and the carbon begins to burn, the flame becomes white, with purple streaks; at this point some scrap is often thrown in if the temperature becomes too high. When, finally, the carbon is burnt out, the flame drops and then a ladle hanging on a hydraulic travelling crane is brought up near the converter, the latter is turned down, and the metal is poured into it, some spiegeleisen having been first added in the converter. The spiegeleisen is a cast iron having a variable but known quantity of manganese and carbon. The converter is now turned over, and the metal is poured into the ladle and carried by the hydraulic crane to a position over the ingot moulds, which are on trucks on the ground; and the melted steel is allowed to run into the ingot moulds through a hole in the bottom of the ladle. The trucks carrying the ingot moulds and ingots are drawn by a little locomotive to the rail mill, near the entrance of which there is an ingenious mechanism for stripping the moulds from the ingots. The ingot is then placed in what might be called a reheating furnace, *i. e.*, one in which heat is applied for the purpose of imparting to it an even temperature throughout. After this the ingot is taken by a hydraulic crane and deposited in a tilting box by means of which it is placed upon the apron of rollers which deliver it to the rolls; then it follows one rolling process after another till it is formed into a rail. Without stopping to discuss the arrangements here, it is plain that not only economy of heat and steam has been taken into consideration, but also economy of labor in handling, besides which a host of engineering problems have been worked out, and are constantly to be worked out. In connection with these works they have established an iron ship-building plant, and are adopting such arrangements as will make it quite extensive when completed, but I shall not describe or comment upon this.

Let us take as our next illustration a textile manufactory, and, as an example, a cotton mill. Here, if we follow the successive steps of the process, we must receive the cotton, unload it, weigh it and store it, separating the different grades. Then, from the storehouse it is carried to the heaters, and, after the bags and hoops are taken off, it is beaten, then passes to the pickers, from there to the carding, then to the slubbing, then to the roving, then to the spinning, whether mule or ring spinning—or some to one, and some to the other—then to the spoolers and warpers. Then the warp goes to the slashers, where it is sized and dried, and then to the looms, where it is woven into cloth, after which it may be treated in various ways. Thus, it may be finished for the market by singeing or shearing, or it may be bleached, or dyed, or printed.

Now, in planning a mill, the first thing to be considered is a proper mill site.

In choosing a site the engineer must consider especially the ease and cost of transportation of raw materials and fuel to the mill, and of the finished product from the mill to the market. If it is near tidewater or near a railroad center it will be favorably situated on these accounts. Nearness to the market, and to the base of supplies, or a situation on a stream where there is an abundant water-power available for the mill, are advantages to be taken into consideration.

Now, when the site has been fixed upon, he must proceed to lay out his mill on paper, and in doing this he must first decide upon the kind of work the mill is to perform, and hence the kind of machinery that is to be used for each process, and the number of machines of each kind, their floor space, weight, etc., also the number of stories of the mill, and also what shall be its dimensions. These latter questions may be determined by the size and shape of the lot of land available, but considerations of light have to do with the determination of the proper width of the mill. He must then proceed to locate his machines on paper so that the processes shall follow each other in proper succession, and so that the material shall pass from one process to the next with as little handling as possible, and a saving in this regard is of very great importance.

When the machinery is all laid out he must arrange his transmission, shafting, pulleys and belts, and decide upon the position for his engine house and boiler house, his belt tower, and his transmission system. Then he must arrange his machines, so as to give the necessary space between and around them for working, and the pulleys on the shafting for driving the machines, so that there shall be no interference.

Of course, the storehouse must be planned and its position relative to the picker house. When this is all done he can determine upon the size of the mill and the position of the walls.

Then he has to determine the probable amount of power required, and thus the size of the engines and boilers.

In all of these determinations he must allow for a reasonable amount of growth, and consider what changes would have to be made, and see that the mill is so built as to admit of them.

Then the engine and boiler house must be planned, the belt tower, and the walls and columns and floors and roof of the mill, and then also its foundation. Also proper regard must be had for protection from fire.

He must ascertain what is the foundation on which he has to build, and he is liable to find that it varies at different points, and that while under some parts the foundation is good, under others it is poor, and he may have to resort to any of the usual engineering expedients to build upon it. Then, of course, the dimensions of the walls, columns, floors, foundations, etc., must all be calculated so that they shall have the requisite strength and stiffness.

Then the work must be executed, and he must see that the materials delivered on the ground are good, and that the work is properly done in all its details.

In determining upon the necessary steam engines and boilers he must take into consideration all the uses for steam in the mill. Thus, there is the heating and possibly ventilating, and also the slashers that require steam, besides which more steam will be required if there is a bleachery or a dye works connected with the mill. According to circumstances we might decide upon one or another kind of engine.

Whatever system of heating and ventilating is adopted must be planned, and all the piping, fans, etc., must be put in and fitted.

Then there must be some source of water supply, capable of furnishing water for the boilers, for drinking, for sanitary purposes, and for a variety of other uses about the mill. Then the drainage must be attended to. After all is built and arranged and the mill is running, questions are always arising as to how certain things can be improved, questions of what oil to use for lubrication, also questions of improvements in the machinery, repairs, etc. And all this is besides the carrying out of the series of processes for which the mill was built and for which it exists. But these processes become, to a very considerable extent, routine matters, though they must be carefully watched and improvements and adaptations made when needed. The superintendents must watch them carefully and must be men skilled in their own departments, and the one who has charge of the mill must also concern himself with them, but his engineering work will usually be larger in amount than the work that he has to perform in direct connection with making the fabric.

[*To be continued.*]

A THEORY OF THE ACTUAL EARTH PRESSURE AND ITS APPLICATION TO FOUR PARTICULAR CASES.

By P. Vedel, C.E., M. West. Soc. Eng.

The actual pressure of a body of earth is in most cases, or practically always, an unknown quantity. Only when a sliding plane is determined beforehand by any local peculiarities, such as a fissure in the ground or a stratum of soft material, may we form an approximate idea of what the actual pressure is, or of what it probably will be. The rational theory of earth pressure which is based upon the differential equations considers the state of limit-equilibrium where all the particles are upon the point of sliding upon each other. It gives, even with this limitation, the solution only for a few special cases, inasmuch as the differential equation of second degree and second order to which it leads is not integrable in its general form. And in those special cases the solution is the same as the one given by the old theory which is based upon Coulomb's principle of the prism of maximum pressure and the assumption of plane sliding surfaces. This theory, considering the limit-equilibrium of the finite Coulomb's wedge instead of the infinitesimal parallelopiped of Cauchy, the coincidence of the results is remarkable.

To know the actual pressure of the earth it would be necessary to trace the minute history of the whole earth body. This historical element, which is usually neglected in theoretical treatises, is evidently of the utmost importance when the actual pressure is required. How the filling was done, the thickness and inclination of the different layers spread out, their subsequent consolidation, exposure to rain and frost and changes of temperature, rise and subsidence of water—these and other historical facts all contribute to determine the actual pressure.

For most practical purposes it is of little interest to know the actual earth pressure. What we want generally is the maximum possible pressure (active pressure) and the minimum possible resistance (passive pressure). If a wall will stand the maximum pressure which can come upon it, then we know it is strong enough. And if it can sustain certain forces applied upon it by the minimum counter-pressure of the earth in front of it, then—supposing its monolithic nature conserved—we are satisfied as to the stability of the structure. It is usual, and, in fact, nearly always sufficiently exact, to adopt the old theory laid down by Coulomb, and further developed and applied by Navier, Poncelet, Culmann, Rebhann, etc. The analytical expressions, first deduced by St. Guilhem, may be reduced to the following formulas for the limit pressures on a solid wall (given, somewhat modified, in Henket, Schols en Telders' Waterbouwkunde, 's-Gravenhage 1885):

$$\left\{\begin{array}{l} P = \frac{1}{2}\gamma \, \frac{H^2 + 2H\,H'}{\cos^2 \varepsilon} \, \frac{\cos(\varepsilon - \omega)\cos(\varepsilon \mp \varphi)}{\cos(\varepsilon - \omega \pm \varphi \pm \varphi')} \, tg^2\left(45^\circ \mp \frac{\theta}{2}\right) \\ K = \frac{1}{3} H \, \frac{H + 3H'}{H + 2H'} \\ \text{where } H' = \frac{\rho \quad \cos\varepsilon}{\gamma \cos(\varepsilon - \omega)}, \; \sin^2\theta = \frac{\sin(\varphi \mp \omega)\sin(\varphi + \varphi')}{\cos(\varepsilon - \omega)\cos(\varepsilon \pm \varphi')} \end{array}\right. \qquad (1)$$

Here P is the pressure on the wall, the maximum active or the minimum passive according as the upper or lower sign is everywhere taken, and K is the vertical distance of its point of application above the base of the back of the wall. Further, H is the total vertical height of the wall; γ the weight of a unit of volume of earth; ρ the load on a unit of the sloping surface of the earth; ω the angle of the slope at which the surface rises from the wall; ε the angle of the battered back of the wall with a vertical; φ the angle of friction or natural slope of the earth; φ' the angle of friction between the wall and the earth or—what Trautwine terms—the wall friction. H' is a fictitious length; θ an angle; both introduced only to simplify the formulas.

In most applications these expressions are modified by special features of each case. In what follows, the wall will be assumed vertical, the surface of the earth horizontal and not surcharged. Hence

$$\varepsilon = 0, \; \omega = 0, \; \rho = 0, \; H' = 0, \; \sin^2\theta = \frac{\sin\varphi \sin(\varphi + \varphi')}{\cos\varphi'}$$

or

$$tg^2\theta = tg\,\varphi \; tg(\varphi + \varphi')$$

and

$$P = \frac{1}{2}\gamma H^2 \frac{\cos\varphi}{\cos(\varphi + \varphi')} \, tg^2\left(45^\circ \mp \frac{\theta}{2}\right) =$$

$$\frac{1}{2}\gamma H^2 \frac{\cos\varphi'}{\cos^2(\varphi + \varphi')} (1 \mp \sin\theta)^2 \qquad (2)$$

For our present purpose we can, however, not content ourselves with these formulas, but must take a more general view of what may actually occur. Considering the earth wedge, it may slide up or down the sliding plane and up or down along the wall, at least relatively. The frictions along the sliding plane and along the back of the wall can act either way, and thus four different classes of cases are possible. The active pressure of the earth will tend to make the wedge slide down along both sliding plane and back of wall; the passive pressure will keep it from sliding upwards along the same planes. The frictions act accordingly either both upwards or both downwards. But when they act different ways, the one upwards and the other one downwards, pressures which may be designated as active-passive or passive-active may occur. The two components into which the weight of the earth wedge is resolved have each one out of two different directions, and hence are different in all four cases.

Confining ourselves at present to a vertical wall with the earth levelled off horizontal and not surcharged, and considering an earth wedge the sliding surface of which, assumed approximately plane, forms an angle β with the horizontal plane, the pressure of the wedge will be:

$$P = \tfrac{1}{2} \gamma H^2 \frac{\cot \beta \sin (\beta - \varphi)}{\cos (\beta - \varphi - \varphi')} \tag{3}$$

where φ and φ' can be both positive (active pressure), the one positive and the other negative, or both negative. The value of β, which makes the pressure maximum or minimum, is found by differentiation of (3). With, as above, $tg^2 \theta$ for $tg \varphi \, tg (\varphi + \varphi')$ the equation

$$\frac{d P}{d \cot \beta} = 0$$

gives

$$\cot \beta = \frac{tg \theta \, tg \left(45^\circ - \frac{\theta}{2}\right)}{tg \varphi} = \frac{\sin \theta}{1 + \sin \theta} \cot \varphi \tag{4}$$

Inasmuch as

$$\frac{d^2 P}{d \cot \beta^2} = - \frac{2 \cos \varphi' \sin (\varphi + \varphi')}{[\cot \beta \cos(\varphi + \varphi') + \sin(\varphi + \varphi')]^3} =$$

$$- \frac{2 \cos \varphi' \sin^3 \theta}{\sin^2 (\varphi + \varphi')}$$

is negative or positive according as $\sin\theta$ is positive or negative the value (4) of β will either correspond to a maximum or a minimum pressure P.

But θ being defined only by the square of its *sin* or *tg*, the question arises what sign it should be given. It may even be questioned whether the equation $tg^2\,\theta = tg\,\varphi \, . \, tg\,(\varphi + \varphi')$ will always be possible, or in other words, whether $tg\,\varphi\;tg\,(\varphi + \varphi')$ may not be negative, and θ consequently an imaginary quantity. If there were no relation between φ and φ' this would certainly occur. But we know that the acting wall friction φ' must always be less than, or at the most equal to, φ; for if the friction between earth and masonry were greater than between the earth particles mutually, then a thin layer would stick to the wall and the sliding occur, not along the wall, but along this layer, where the angle of friction is φ. Hence, whether φ or φ', or none or both of them is negative, $tg\,\varphi\;\; tg\,(\varphi + \varphi')$ will always be positive. With reference to the sign of θ, it will by inspection of (4) be evident that it should be taken positive or negative according as φ is positive or negative, for $\cot\beta$ must be positive if an earth wedge is actually formed. Equation (4) will therefore correspond to a maximum pressure whenever the wedge tends to slide down the sliding plane, *i. e.*, when φ is positive as for the active earth pressure; but it will correspond to a minimum when the wedge tends to slide up the sliding plane, *i. e.*, when φ is negative as for the passive earth pressure.

Transforming (3) by means of (4), we find the expression (2) for the maximum or minimum pressure, or

$$P\,\frac{max}{min} = \tfrac{1}{2}\gamma H^2\,\frac{\cos\varphi}{\cos(\varphi+\varphi')}\,tg^2\left(45^\circ - \frac{\theta}{2}\right) =$$

$$\tfrac{1}{2}\gamma H^2\,\frac{\cos\varphi'}{\cos^2(\varphi+\varphi')}\,(1 - \sin\theta)^2 \qquad (5)$$

Likewise will equations (1), taken with the upper signs, represent the general formulas for P *max.* and P *min.* when φ, φ' and θ are taken with their respective signs.

With a view of representing the results of this analysis in a more conspicuous manner the annexed diagram has been constructed. For the four different cases the variation of the active, passive-active, active-passive and passive earth pressure with the angle β is shown by the respective curves. On lines drawn from the lower edge of the wall under a variable angle β with the horizon the corresponding values of P (3) and P *max.* or P *min.* (5) are set out as radii vectores, and thus the curves were plotted. Only values of β between 0 and 90° were considered and the curves are dotted where the formula makes P negative. As physical constants were taken:

$$\varphi = \pm\ 30^\circ,\ \varphi' = \pm\ 25^\circ, \text{ and } \tfrac{1}{2}\,\gamma\, H^2 = 1.$$

The following table supplements the diagram:

TABLE OF VALUES OF $P \div \frac{1}{2}\gamma H^2$.

I = active. II = active-passive. III = passive-active. IV = passive.

Angle β	I φ pos., φ' pos.	II φ pos., φ' neg.	III φ neg., φ' pos.	IV φ neg., φ' neg.
0°	$-\infty$	$-\infty$	$+\infty$	$+\infty$
10°	− 2·743	− 1·947	+ 3·774	+ 8·625
$15^\circ\ 43'\ 18''$				+ 7·70294
20°	− 0·582	− 0·494	+ 2·322	+ 8·133
30°	0	0	+ 1·831	+ 17·218
35°				$\pm\infty$
40°	+ 0·214	+ 0·253	+ 1·584	− 12·858
45°	+ 0·263	+ 0·338	+ 1·503	− 5·562
50°	+ 0·288	+ 0·406	+ 1·441	− 3·192
$55^\circ\ 9'\ 4''$	+ 0·29593			
60°	+ 0·290	+ 0·503	+ 1·366	− 1·366
$64^\circ\ 3'\ 20''$			+ 1·35760	
70°	+ 0·242	+ 0·553	+ 1·385	− 0·625
$72^\circ\ 42'\ 8''$		+ 0·55661		
80°	+ 0.149	+ 0·522	+ 1·902	− 0·191
85°			$\pm\infty$	
90°	0	0	0	0

It is self-evident that for φ positive can β never be $< \varphi$, and the diagram shows this plainly by the pressure being negative for such values of β. For φ negative, on the contrary, β can be both $> \varphi$ and $< \varphi$.

* * *

The general formulas arrived at in the preceding investigation will now be applied to the following special cases:

(1) A cylindrical, circular, vertical vessel, the radius of which is R, is filled with earth up to a certain height, H. The bottom is not connected to the cylindrical surface. The weight of earth, carried by this bottom, is required.

(2) The same cylindrical vessel is filled with earth to the same level. What force must be exerted from beneath on the bottom in order to push it, with the earth it carries, upwards through the cylinder?

(3) A similar cylinder of radius R has, in some way or another, been gotten down to a depth H into a body of earth, the upper surface of which is horizontal, but else unlimited downwards and to all sides. What steady pressure is necessary to push this cylinder further down?

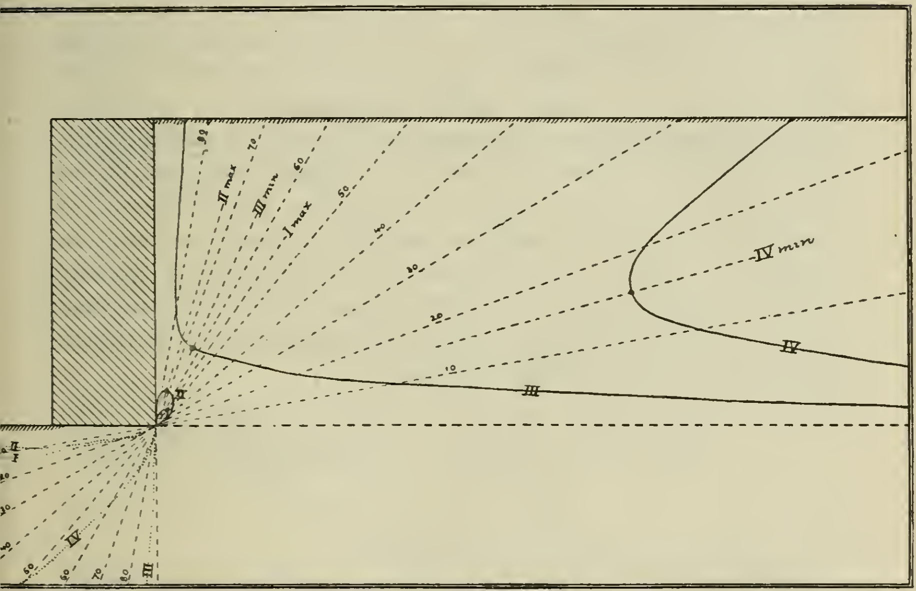


FIG. 1.

(4) The same cylinder reaches down to the same depth in the earth. What steady pull is necessary to pull it up?

The bearing of the latter two cases upon the question of pile-driving (or rather the load which can be supported by a pile) and pile-pulling lends a particular interest to them.

In all four cases if P_1 be the actual pressure per unit length on a plane element along a generatrix of the cylindrical surface and consequently $P_1 \sin \varphi'$ the frictional resistance; then the total friction on the cylindrical surface is $2 \pi R . P_1 \sin \varphi'$. But the value of P_1 corresponding to any given sliding plane is not the same as P of (3). For P is the pressure on a unit length of an infinitely long plane wall deduced from consideration of a prismatic wedge of earth; but P_1 must be the pressure of a wedge the two sides of which, instead of being parallel, are radial planes through the axis of the cylinder. Hence, P_1 to P as the ratio of the volumes of the two wedges.* Denoting by V_1 and V these volumes, the ratio is easily found to be

$$\frac{V_1}{V} = 1 \mp \frac{H}{3\,R}\, cot.\, \beta \tag{6}$$

where the upper sign refers to the two first cases (*i. e.*, the earth inside the cylinder), and the lower sign refers to the two last cases (*i. e.*, the earth surrounding the cylinder). This formula, however, is applicable only on the assumption that the sliding planes and wedges can actually be formed complete and without intersecting each other or, in other words, that the earth around the cylinder extends far enough and that the diameter of the cylinder is greater than or equal to $2\,H\,cot.\,\beta$. When the latter is not the case or $R < H\,cot.\,\beta$, then to the above formula taken with the upper sign is to be added another term,

$$\frac{V_1}{V} = 1 - \frac{H}{3\,R}\, cot.\, \beta + \frac{(H\,cot.\,\beta - R)^3}{3\,R\,H^2\,cot.^2\,\beta} =$$

$$\frac{R}{H}\, tg\, \beta\ \left(1 - \frac{R}{3\,H}\, tg\, \beta\right) \tag{7}$$

Evidently the value of β or the angle of the wedge which in each case makes P_1 a maximum or a minimum is different from the one given by (4). Differentiating the expression,

$$Q = \frac{cot\,\beta.\, sin\,(\beta - \varphi)}{cos\,(\beta - \varphi - \varphi')}\ \left(1 \mp \frac{H}{3\,R}\, cot.\, \beta\right)$$

and equating

$$\frac{d\,Q}{d.\, cot.\, \beta} = o$$

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* Rankine's or the rational theories would not agree with this proportioning. But considering what will actually happen, it seems admissible as a fair approximation.

we find

$$x = cot.\ \beta.\ cot.\ \theta.\ tg\ \varphi$$

as root of a somewhat complicated equation of the third degree, to wit :

$$x^3 - \tfrac{1}{2}\ cot.\ \theta\ (1 \pm \frac{3\,R}{H}\ tg\ \varphi - 3\ tg^2\ \theta)\ x^2 -$$

$$(1 \pm \frac{3\,R}{H}\ tg\ \varphi)\ x \pm \tfrac{1}{2}\,\frac{3\,R}{H}\ tg\ \varphi.\ cot\ \theta = o \qquad (8)$$

To solve this equation approximately we take as a first approximation

$$x = tg\left(45^\circ - \frac{\theta}{2}\right)$$

or $cot\ \beta$ the same as (4). Newton's rule then gives as a second approximation

$$x = tg\left(45^\circ - \frac{\theta}{2}\right)\left(1 - \frac{\tfrac{1}{2}}{1 - 2\ sin\ \theta \pm \frac{3\,R}{H}\ tg\ \varphi\ (1 + sin\ \theta)}\right)$$

Hence the value of $cot\ \beta$ is the same as the one given by (4) multiplied by the term in brackets or the factor

$$f = 1 - \tfrac{1}{2}.\ \frac{1}{1 - 2\ sin\ \theta \pm \frac{3\,R}{H}\ tg\ \varphi\ (1 + sin\ \theta)} \qquad (9)$$

Here the upper sign refers to the cases where the earth is inside the cylinder, the lower sign to where it is outside. When the earth is inside, and

$$R < f\,H\ \frac{sin\ \theta}{1 + sin\ \theta}\ cot\ \varphi$$

the values of β which make P_1 a maximum or minimum are found by substituting (7) for (6) in the expression for Q before differentiating. The equation by which

$$y = tg\ \beta$$

is determined will be of the second degree, to wit:

$$y^2 + 2\, tg\, \varphi .\, cot^2\, \theta .\, y - \left(tg^2\, \varphi .\, cot^2\, \theta + \frac{3\, H}{R}\, \frac{tg\, \varphi}{sin^2\, \theta} \right) = o$$

whence

$$y = tg\, \beta = -\, tg\, \varphi\, cot^2\, \theta \pm \frac{1}{sin\, \theta} \sqrt{tg^2\, \varphi\, cot^2\, \theta + \frac{3\, H}{R}\, tg\, \varphi} \qquad (10)$$

which, according to our supposition, must be

$$< \frac{H}{R}$$

Comparing now equations (3), (6) and (7), we deduce the following formula for the total friction, F, on the cylindrical surface:

$$F = 2\, \pi\, R\, P_1\, sin\, \varphi' = \pi\, \gamma\, R\, H^2\, \frac{cot\, \beta .\, sin\, (\beta - \varphi)}{cos\, (\beta - \varphi - \varphi')} \left(1 \mp \frac{H}{3\, R}\, cot\, \beta + A\right) \qquad (11)$$

Here the upper sign refers to the case where the earth is inside the cylinder and the lower sign to where it is outside; and A is in the latter case always naught and in the first case

$$A = \begin{cases} \dfrac{(H\, cot\, \beta - R)^3}{3\, R\, H^2 .\, cot^2\, \beta} & \text{for } R < H\, cot\, \beta \\ o & \text{for } R > H\, cot\, \beta \end{cases}$$

The maximum and minimum values of F will correspond to β determined by the equation

$$cot\, \beta = f .\, \frac{tg\, \theta .\, tg \left(45^\circ - \dfrac{\theta}{2}\right)}{tg\, \varphi} = f\, cot\, \varphi .\, \frac{sin\, \theta}{1 + sin\, \theta} \qquad (12)$$

where f is defined by (9); or, when the earth is inside the cylinder and

$$R < H\, cot\, \beta$$

by the equation

$$cot\, \beta = \frac{tg\, \theta}{tg\, \varphi}\, \frac{sin\, \theta}{-\, cos\, \theta \pm \sqrt{1 + \dfrac{3\, H}{R}\, tg^2\, \theta .\, cot\, \varphi}} \qquad (13)$$

[*To be concluded.*]

INVESTIGATION OF A BITUMEN FROM PARK COUNTY, MONTANA.*

By Wm. C. Day and A. P. Bryant.

Although asphalt and allied materials are known to occur at many localities in the United States, comparatively little has been accomplished in the way of their analysis and investigation. Results thus far secured have been confined chiefly to a few sources favorably situated for transportation at low rates. The available supply of asphalt at present largely exceeds the demands. Since, however, the uses to which this material may be applied are increasing, and since, further, no one source yields a product suitable for all purposes we have thought it worth while to place on record the facts and figures secured in connection with a material from a new source in the West.

The substance under consideration was taken from the property of Mr. C. J. Lakin, of Miles City, Montana.

The sample consisted of about one liter of a brownish-black material, liquid enough to flow very slowly at ordinary temperatures, and possessed of an unpleasant and quite pronounced odor.

ANALYSIS.

Determination of Water.

0·4647 grams of bitumen gave 0·0314 grams of water absorbed in a chloride of calcium tube after two hours heating in a U tube immersed in boiling water; a current of dry air was passed through the tube during this time.

Percentage of water found, 6·76.

There was no evidence whatever of any change in the material other than the loss of water.

Determinations of Carbon and Hydrogen.

No. 1.—0·6462 grams of substance gave 1·8672 grams of carbon dioxide and ·5365 grams of water.

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* Read at the stated meeting of the Chemical Section, held June 19, 1894.

No. 2.—0·4097 grams of substance gave 1·2144 grams of carbon dioxide and ·3449 grams of water.

Carbon found, No. 1, 78·80, No. 2, 80·81.

Hydrogen found, No. 1, 9·22, No. 2, 9·35.

Determination of Mineral Matter.

No. 1.—0·8426 grams of substance gave on combustion 0·0058 grams of residue.

No. 2.—0·3324 grams of substance gave on combustion 0·0023 grams of residue.

Percentage of ash, No. 1, 0·69 per cent.

Percentage of ash, No. 2, 0·69 per cent.

Determination of Sulphur.

0·7144 grams of substance gave (using Liebig's method) 0·1471 grams of barium sulphate.

Percentage of sulphur found, 2·83.

A determination of nitrogen gave only a trace.

The following analysis of commercial interest was also made:

MATERIAL SOLUBLE IN CARBON DISULPHIDE.

5·5300 grams of dry substance gave 5·2540 grams of material (bitumen) soluble in carbon disulphide.

Percentage of bitumen found, 95·00.

The weight of the material insoluble in carbon bisulphide was 0·2760.

Percentage of foreign organic matter, 4·99.

The material soluble in carbon disulphide was treated with gasoline, and the percentage of matter soluble in gasoline (petrolene) was thus determined.

5·5300 grams of the original substance gave 4·4240 grams of material soluble in gasoline.

Percentage of petrolene found, 80·00.

The foreign organic matter found consists largely of fragments of birds' feathers, leaves and insects, which had probably accidentally been caught and submerged in the pitch.

The following distillation experiments were made:

Seventy-four grams of the substance were introduced into a distilling flask by aid of a filter pump; the viscosity of the material was such that it took several hours to transfer about 100 cubic centimeters to the flask.

A Bunsen flame was applied directly to the flask; the material frothed considerably, giving a gas which was collected and measured. The gas given off at this stage amounted to 2,250 cubic centimeters. When a thermometer placed with the bulb in the vapor (*i. e.*, a little below the side tube of the distilling flask) showed 98° C. the frothing ceased and a liquid distilled over between 98° and 110°; the weight of this fraction was 6·75 grams. The second fraction was taken between the limits 110° and 170°, its weight was 2·3 grams; the third fraction was taken between 170° and 225°; its weight was 8·75 grams; the last fraction was from 225° to the limit of the thermometer; it weighed 22·5 grams. The last fraction was accompanied by the more rapid evolution of gas which had decreased at 98°. Between 98° and 225°, 1,000 cubic centimeters of gas were produced.

The amount of gas evolved at this final stage was 2,500 cubic centimeters, thus making in all 5,750 cubic centimeters of what, on burning, proved to be a good illuminating gas.

A number of tests for aromatic hydrocarbons and derivatives yielded negative results.

The following summary of the analytical results obtained shows how the material in question compares in chemical constitution with Trinidad asphalt, which has heretofore supplied a large percentage of the demand in the United States:

	*Trinidad.**	*Park Co., Montana.*
Water,	—	6·76
Carbon,	85·89	79·81
Hydrogen,	11·06	9·29
Oxygen,	·56	·62†
Nitrogen,	—	trace.
Sulphur,	2·49	2·83
Ash,	—	0·69
	100·00	100·00

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* Analyst, Bowen.

† By difference.

These figures are only approximately comparable, since those for the Trinidad material are calculated on the pure and dry asphalt, exclusive of earthy and foreign organic matter.

A comparative investigation of gilsonites and asphalts from a number of new sources in the United States is now being carried out by the authors, and the present paper may be regarded as preliminary to a more comprehensive one, which, it is hoped, may be presented in the fall.

SWARTHMORE COLLEGE,
Swarthmore, Pa., June 19, 1894.

ANTHRACITE COAL NEAR PERKIOMEN CREEK.*

By OSCAR C. S. CARTER,
Prof. Geology and Mineralogy, Central High School, Philadelphia.

A vein of coal twenty-six inches thick has been discovered on the Shirley farm at Arcola Station, on the Perkiomen Railroad, about twenty-five miles from Philadelphia. The vein is located near where the Skippack Creek empties into the Perkiomen Creek. An expert miner has been working on the vein for the past three weeks, and pronounces the coal of fine quality. A company is being formed for the purpose of working the coal. There are a number of smaller veins in the immediate vicinity, and it is thought that coal can be mined in large quantities on this and the adjoining farms. Several mining experts from Pottsville were at Arcola and examined the outcroppings of coal, and pronounced the indications the very best, and before leaving made a liberal offer for the farm. Work has been temporarily suspended on account of the water flowing in from the creek.

The above notes of January 6, 1894, are from local newspapers. A visit to the locality showed me that the coal seam is found at the base of a high hill, which slopes steeply to the Skippack Creek, near where it empties into the Perkiomen. The rock in the vicinity is red sandstone of triassic age, and numerous exposures along the Skippack show that it dips gently at angles of from 12° to 15°. The sandstone is not a conglomerate, but is similar to that seen along the Schuylkill from Norristown to Phœnixville. At the base of the hill, on a level with the creek, is found a bed of hard, black carbonaceous slates. These are conformable with the sandstone, but the line of contact is sharp. These slates contain iron pyrites, and many pieces show a play of colors like iridescent coal. The sandstone resting on the slates is over 100 feet in thickness. The coal is found in the slate, about four feet from the top of the slate bed. The coal seam is said to be twenty-six inches thick at the widest part, but gradually thins out until it becomes an inch thick. The hole was partially filled with ice at that time, so that the true thickness could not be determined. Coal outcrops along the banks of the stream near the water-line; about one ton had been taken out. Two men were at work running a tunnel through the hill and supporting it with heavy timbers. One of the old residents of the township informed me that it was known many years ago that there was coal in the hill, and that fifty years ago Mr. Peters, who then owned the farm, ran a shaft through the hill for a distance of 100 feet; it was kept on an incline so as to drain off the water. In the middle of this passage-way they sank a shaft ten feet deep. The shaft unfortunately was in the sandstone and did not reach the slate, which holds the coal. This old shaft is now filled up. An examination of the slate and coal thrown out failed to show any fossils, but Mr. Shirley informed me that he had found one which resembled a poplar leaf. Several specimens of coal were secured for analysis. It is a hard, compact and lustrous anthracite. On analysis I found:

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* Read at the stated meeting of the Chemical Section, held June 19, 1894.

Volatile and combustible matter,	6 50
Fixed carbon,	62·84
Ash,	30·6

This sample contained some slate, which accounts for the high percentage of ash. I made an analysis of another specimen much purer, which showed it to be a good coal:

Water,	·95
Volatile and combustible matter,	5·83
Fixed carbon,	83·8
Ash,	9·50
	100·08

A furnace assay showed that one gram of coal reduced 31·78 grams of lead from litharge, thus showing from the usual calculation that its value in units of heat is 7,552.

The following table is given for comparison:

	Heat Units.
Peat	= 3,000
Wood	= 4,000
Lignite	= 5,000
Carbon	= 8,080
Hydrogen	= 34,462

On the country road between Eagleville and Arcola was noticed a red-and-white sandstone, containing irregular black patches of organic matter. On splitting the rock, layer after layer of this black carbonaceous matter was seen. The sandstone was white where in contact with, or near to, the organic matter, but was red some distance off. The red coloring matter of the sandstone is due to red hematite. This is a fine example of organic matter, acting as a reducing agent and reducing the ferric oxide (hematite), which is insoluble in water to ferrous oxide, which is soluble in water containing carbonic acid gas. Water filtering through the bed planes had dissolved the ferrous oxide and thus leached out the red coloring matter of the sandstone, leaving it white.

Precisely the same kind of rock as the above was noticed in the new red sandstone belt in a quarry near Three Tuns, about three miles from Ambler.

The triassic coals are exceedingly interesting from a geological standpoint, because they occur in more recent formations than coals of the carboniferous period and are thus of a later age. There are other instances of the occurrence of coal in Montgomery County. In the new red sandstone at Norristown, on Elm Street near the Stony Creek Railroad, a seam of coal an inch in thickness was found. It only extended for a few feet and was not very wide. It was found about twelve feet below the surface, while grading the street. I also found the striated stem of a fossil plant in the sandstone.

[See "History of Montgomery County," p. 17.]

This coal was of a deep black color, pitchy in appearance, very brittle and broke with a conchoidal fracture.

At Gwynedd, Montgomery County, in the new red, is found a bed of carbonaceous shale, colored black by traces of coaly matter which it contains. In Lower Providence Township, Montgomery County, about one-half mile west of the Trooper was found a seam of coal three inches thick. It was used by the village blacksmith. During the summer of 1883, men working upon the new tunnel at Phœnixville discovered a two-inch seam of coal in the sandstone. . It may be that a patient examination of these so-called triassic slates, which underlie the sandstone in Montgomery County, will disclose beds of workable coal in more than one locality. No systematic search has ever been made for coal and very few deep artesian borings have been made in the new red in Montgomery County. In drilling the deep artesian well at Lansdale, a bed of black carbonaceous slates was passed through, and under these slates was found a bed of coal. Dr. A. D. Markley, of Hatboro, informs me that a thick bed of coal was passed through in drilling an artesian well at North Wales; it was found at a depth of 150 feet. These same triassic rocks have yielded large quantities of good coal in Virginia and North Carolina. In the earliest days of coal mining, more coal was taken from the red sandstone rocks of the Richmond basin than was mined in Pennsylvania. In 1822, about 48,000 tons were produced, which was twelve times the amount shipped by Pennsylvania. (See "Mineral Resources," 1886.) In 1833, about 142,587 tons of triassic coal were mined in Virginia, or about one-third the amount of anthracite produced in Pennsylvania. In 1887 but one mine was worked, and it produced 30,000 tons. During this year several new companies were organized to mine coal in this field. The triassic field in Virginia has an area of 180 square miles; about two square miles of territory have been worked over. These coal beds occur in an immense sandstone trough which rests on a granite floor; the coals are mainly bituminous, although a natural coke is mined. This coke was formed by an intrusion of trap. An average analysis of Richmond coal gives:

Water	1·34
Volatile matter	32·45
Fixed carbon	57·05
Sulphur	1·98
Ash	7·18

In North Carolina, triassic coals are mined near the Deep and Dan Rivers. In the Dan River field, two coal beds have been found; one bed of soft coal has a thickness of five feet; the other, of harder coal, has a thickness of three feet. On the opposite side of the valley, a bed of soft coal, free from slate and nine feet in thickness, has been found; some good anthracite has also been found. Mr. Robson, who has been exploring the district, says: the Dan River coal deposits may be taken as available for fuel supplies for a distance of fifty miles; the width of the basin is three and one-half miles. He has driven 800 feet of adits, in length from thirty down to twenty feet, and ascertained the existence of persistent seams of coal over five feet in thickness. These coals are high in sulphur. The coal of the Deep River is also high in sulphur, averaging about three per cent.; it occurs in dark, carbonaceous slates and shales, and has been found for a distance of thirty miles along the outcrop. During the late war, about 50,000 tons were taken out to supply the blockade runners at Wilmington and also to supply the arsenals. The following is an average analysis:

Moisture	1·79
Volatile and combustible matter	29·56
Fixed carbon	58·30
Ash	7·46
Sulphur	2·89
	100·00

JOHN HOWARD GIBSON.

John Howard Gibson, whose untimely death cut short what promised to be a career of exceptional usefulness, was born March 13, 1857, and died April 6, 1894, having just completed his thirty-sixth year. Mr. Gibson was the son of Henry Clay Gibson, one of Philadelphia's most prominent citizens and well known as a liberal patron of the fine arts, and his wife, Mary Klett.

He was graduated from the University of Pennsylvania in the class of 1877. His connection with the Franklin Institute began in 1878, when he was elected to membership. He manifested from the beginning of this connection a warm interest in its affairs and remained to the end of his life one of its most active members and officers. He was especially interested in the growth of its library and served most acceptably for a number of years on the Committee on Library.

He was elected a member of the Board of Managers in the year 1893, and at once made his influence felt in that body by his activity in promoting every movement looking to the advancement of the interests of the institution. His conspicuous advocacy in the Board of measures having for their object to secure for the Institute a new building, awakened a renewed interest in the subject among his colleagues, and whether this important object shall be realized sooner or later, the Institute owes a debt of gratitude to its deceased officer for his unflagging zeal in endeavoring to bring it about.

His personal relations with his colleagues of the Board and fellow-members were characterized by uniform courtesy and amiability.

The manner of his untimely taking off was peculiarly sad. His children, to whom he was devotedly attached, were afflicted with a contagious malady, which, in his solicitous attendance upon them, he contracted, and which, within a few hours, terminated his life. Thus, all too early was closed a life which, had it been spared, would have been devoted to noble and unselfish objects; and the Franklin Institute, in whose work he took special pride, and in whose future he had unbounded faith, may well regret the loss of a friend so devoted to its interests, and so willing to give freely of his time and energy and means to serve it.

Mr. Gibson married Susan Worrall, daughter of Frederick Sickel Pepper, of Philadelphia, by whom he had three children. His widow and children survive him.

F. LYNWOOD GARRISON.
WILLIAM H. WAHL,

Philadelphia, June 8, 1894.

Accepted at the stated meeting of the Board of Managers June 27, 1894, and ordered to be referred to the Committee on Publications and reported to the Institute.

H. L. HEYL, *Actuary.*

BOOK NOTICES.

The Mineral Industry, its statistics, technology and trade, from the earliest times to the close of 1893. New York: Scientific Publishing Company, 1894. 4to. Pp. 894. Price, $5.

The second volume of *The Mineral Industry*, edited by Mr. Rothwell, with the assistance of a number of collaborators, is a comprehensive review, technical and commercial, of the mining and metallurgical industries of the world. Each branch of the subject has been confided to an expert thoroughly familiar with the subject, and the result is the production of a volume which gives in concise encyclopædic form the latest and most approved methods in use for producing, selecting and refining the useful minerals and metals, and the amounts and values of each produced and consumed in all parts of the world. The work is remarkably comprehensive, and many of the special articles are extremely valuable contributions to the history of the art to which they relate.

The work is beyond comparison in thoroughness with anything of the kind produced elsewhere, and its value to the engineer, the metallurgist, the man of business and the statistician, cannot be over-estimated. Its compilation represents an enormous amount of work, demanding the highest order of special skill and knowledge, and its successful completion reflects the highest credit upon its accomplished editor. W.

The Metallurgy of Lead and the Desilverization of Base Bullion. By H. O. Hoffman, E.M., Ph.D. Second Edition. The Scientific Publishing Co., New York, 1894.

No branch of metallurgy, except the manufacture of pig iron and steel, has made more rapid progress in the United States than the smelting of argentiferous lead. A new treatise on this subject has been a desideratum for many years. Professor Hoffman has now supplied this want and presented us with a book which is thoroughly modern, and which must be regarded as one of the most valuable recent contributions to the literature of metallurgy. It is admirably planned and well written. After some introductory chapters on the history of the metal, and its occurrence and distribution in nature, the author gives an account of the manner in which ores are bought and received by the smelting works, including the methods of sampling and assaying. The main part of the book is devoted to the discussion of the metallurgical treatment of the ores, and this is followed by descriptions of the various processes of desilverizing the base bullion.

Considerable space is allotted to theoretical discussions, and, wherever possible, the chemical reactions are explained. The descriptions of metallurgical operations and appliances are very accurate and complete, special prominence being given in this respect to modern American practice.

The value of the book is greatly enhanced by numerous illustrations, which are mostly drawn to scale.

The rapid technical methods of analysis, of which accurate and detailed directions are given, will doubtless prove very acceptable to a large class of readers. H. F. K.

Hendricks' Architects' and Builders' Guide and Contractors' Directory of America. Fourth Edition. New York: S. E. Hendricks & Co. 1894. 4to. 800 pp. Price, $5.

The scope of this useful reference book will appear from the following explanatory statement quoted from the publishers' prospectus: "This complete dictionary of all the constructive industries of the United States contains over 175,000 names, addresses and business classifications, comprising builders and contractors of material and construction in the building and kindred industries; with full lists of the manufacturers of, and dealers in, everything employed in the manufacture of material and apparatus used in those industries, from the raw material to the manufactured article, and from the producer to the consumer." The contents embrace also an extensive list of American architects, including those of Canada, Cuba and Mexico.

As will be perceived from the foregoing, the work is designed to be a professional and business directory, covering every branch of the arts and industries connected with building construction. The classification adopted is elaborate but very convenient. Thus, in the index of contents will be found every variety of brick, each classified under its special heading; and the same elaboration has been applied apparently to the other trades, such as engineers' supplies, boiler makers, heaters, heating specialties, plumbers' supplies and specialties, slate, cements, building stone, roofing tiles, pumps, sheet metal goods, fire-proof building materials, etc.

So far as we are competent to judge of the merits of a work of its class, the directory is unusually comprehensive, and admirably classified for reference, and we have no reason to question that it is as accurate as, in the nature of things, a work of the kind can be made. It should prove an extremely handy reference book for all having to do with building construction. W.

Wilson's Cyclopædic Photography: a complete hand-book of the terms, processes, formulæ and appliances available in photography, arranged in cyclopædic form for ready reference. By Edward L. Wilson, Ph.D. New York: Published by Edward L. Wilson, No. 853 Broadway. 1894. Large 8vo. 522 pp. Price, $4.

The author's long experience as a photographer and photographic journalist and author, qualifies him perhaps better than any other expert to undertake the preparation of a work of the character of this one. So far as a general knowledge of the subject enables us to judge of the merits of the work, it is comprehensive, concise and accurate, and it should prove specially useful to the class for whose benefit it has been prepared. The arrangement is alphabetical by subjects, the catch-word or words are distinctly displayed in black body-letter, and the type is large and clearly printed. The numerous illustrations, many of which have been prepared especially for the work, add to its value. W.

The Transition Curve by Offsets and by Deflection Angles. By C. L. Crandall, C.E., Associate Professor of Civil Engineering, Cornell University. New York: John Wiley & Sons. 1893. Price, $1.50.

The author believes that in this little book are developed for the first time accurate methods for applying the true transition curve, or that curve in which the curvature increases directly with the distance, to curves of large total deflection and to both the deflection and the offset methods.

The book is intended primarily for use by students of civil engineering in colleges, but it is believed that the complete set of tables given will render the methods here explained at least as rapid and convenient in actual use in the field as are the more restricted or the merely approximate methods now in use. T.

Surveying and Surveying Instruments. By G. A. T. Middleton, Associate of the Royal Institute of British Architects. New York: Macmillan & Co. 1894. Price, $1.25.

This work is a reprint of a series of articles which have appeared in the *Building News.* It is strictly elementary, and proposes simply to describe concisely the operations and instruments used in land surveying. It is, of course, based upon English methods, and it is therefore not strange that the theodolite comes in for description and illustration. The work is pretty freely illustrated by photo-engravings, which rather lack in clearness and in firmness of lines. T.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS

ERRATUM.

By a mistake in reproducing *Fig. 1* in the article on "The Graphics of the Efficiencies of the Steam Engine," by R. H. Thurston, in the August number of the *Journal*, the scale of that plate has been rendered inaccurate, the lower division and zero-line having been cut off and the scale carried up irregularly. As printed, the lowest line should be marked "4" and the next "8," and so on upward, bringing the figure "40" correctly at its present location.

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published originally in a paper presented to the American Society of Mechanical Engineers. This seems to have been the first attempt to frame a practically applicable theory of the various efficiences with which the engineer has to deal in designing and constructing this class of apparatus, and the first presentation of the algebraic theory of the physical and the commercial aspects of the several problems which arise in the adaptation of the steam boiler to its location and work, having due regard to the costs and to the condition of the labor and money markets.* It was supplies and specialties, slate, cements, building stone, roofing tiles, pumps, sheet metal goods, fire-proof building materials, etc.

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* *Transactions of the American Society of Mechanical Engineers*, April, 1882; *Journal of the Franklin Institute*, July, 1882.

So far as we are competent to judge of the merits of a work of its class, the directory is unusually comprehensive, and admirably classified for reference, and we have no reason to question that it is as accurate as, in the nature of things, a work of the kind can be made. It should prove an extremely handy reference book for all having to do with building construction. W.

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[illegible]

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VOL. CXXXVIII. SEPTEMBER, 1894. No. 3

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE GRAPHICS OF THE EFFICIENCIES OF THE STEAM BOILER.

BY R. H. THURSTON.

A study of the several efficiencies of the steam boiler was made by the writer some years ago, and the results published originally in a paper presented to the American Society of Mechanical Engineers. This seems to have been the first attempt to frame a practically applicable theory of the various efficiences with which the engineer has to deal in designing and constructing this class of apparatus, and the first presentation of the algebraic theory of the physical and the commercial aspects of the several problems which arise in the adaptation of the steam boiler to its location and work, having due regard to the costs and to the condition of the labor and money markets.* It was then shown that there are two principal efficiencies which the designing engineer must consider in proportioning a proposed boiler plant, and two subsidiary efficiencies—perhaps, more correctly, financial measures of efficient use of capital—which he may find to assume some importance when the boiler in question is one in actual operation. These so-called efficiencies are:

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* *Transactions of the American Society of Mechanical Engineers*, April, 1882; *Journal of the Franklin Institute*, July, 1882.

(1) The efficiency of the steam boiler in the accepted sense of that phrase; the ratio of the quantity of heat stored in making steam to the amount set free in the furnace.

(2) The commercial efficiency of the operation; which efficiency measures the approximation of the utilization of capital in the given case to that highest attainable productiveness which it is the principal duty of the engineer to seek in all cases.

(3) The commercial efficiency of a given boiler plant; which, when a maximum, involves the apportioning of such an amount of work to the plant as will give highest returns in value of product.

(4) The commercial limit of efficiency with increasing demand for steam.

The first two efficiencies are of interest to the designing engineer, who has for his task the proportioning of boilers to a stated, definitely prescribed, demand for steam; the second are of importance to the proprietor who desires to increase the product of a boiler plant previously constructed for a stated power. The first two enter the problem: Given: the quantity of steam required; what size and proportions of boiler shall be supplied to produce it? The second two relate to the problem: Given: a steam plant constructed and in operation; what amount of steam can be demanded of it with maximum profit to the owner? what amount can be made without exceeding the limit cost, plus a fair business profit? In the first set of problems, the variable is the size of boiler for a stated power; in the second it is the power to be demanded from a known extent of boiler heating surface.

The first of these efficiencies is the product of a number of what we will call "efficiency-factors," as the efficiency of heat-development by more or less complete combustion; the efficiency of heat-transfer from furnace to the water and steam in the boiler; the efficiency of transfer from boiler to engine. The second on the list above involves the first and includes the consideration of the costs of construction, placing and operating, in such manner as to determine what proportion of boiler will give the highest total return on the capital invested or continuously expended. The last two efficiencies relate to use of capital with highest results, or up to a limit set by what would be considered fair and acceptable returns. The outcome of the investigation above referred to was in brief the following:

Expenses of Operation may be reckoned under three heads:

(1) Those costs of boiler and of maintenance, reckoned as annual expenses which depend upon original magnitude of investment in boiler, accessories and necessary incidental costs, as interest or loss of profit on money invested in boiler, house, land occupied, taxes, insurance, repairs, depreciation and sinking fund for ultimate replacement, etc.; which costs are all more or less directly variable with the size of boiler adopted.

(2) Those regular annual expenses which are incurred in the operation of the boiler, as costs of fuel, transportation, firing, removal of ash, storage, if any, freight in cases of locomotive and steamship operation; and, usually, some costs attendant upon incidental operations. These costs are variable with, and may commonly be taken as proportional to, quantity of fuel consumed.

(3) Expenses which do not vary with either size of boiler, in the particular case assumed, or with quantity of fuel burned, and which may, therefore, for the problem in hand in any given case, be taken as constant.

All variable expenses may be classified in this manner into the treasurer's account of investment expenditure and returns, and the working expenses of the boiler-room, and assigned, accordingly, to classes one and two. Examples of the first class are the interest and insurance accounts; of the second class are costs of fuel, in the furnace; of the third are chief engineer's salary, fire risks on adjacent property, etc.

Efficiencies are computed as follows:

Let

A = constant in Rankine's expression for boiler efficiency.

B = ditto.

C = cost—Class II—of fuel per annum per pound burned per hour on one square foot, *i. e.*, of one pound of fuel per hour for a working year.

D = annual investment, Class I, per square foot of heating surface of boiler.

E_1 = water-evaporating power of the fuel for unity efficiency.

E = evaporating power for computed efficiency.

F = weight of fuel burned on the square foot of grate.

S = area of heating surface per square foot of grate.

The efficiency of the steam boiler may be computed with fair approximation by employing Rankine's formula

$$E = BE_1 \div (I + AF/S) \tag{1}$$

The costs of supplying steam, as an annual charge, will be

$$P = DGS + CFG; \tag{2}$$

and the profitable work done is measured by the weight of steam made,

$$W = FGE; \tag{3}$$

while their ratio, which is made a minimum by proper adjustment of the area of heating surface, is

$$y = P \div W = (CF - DS) + EF. \tag{4}$$

Introducing the value of E, from (1), and differentiating for a minimum, we obtain

$$S = F\sqrt{\frac{AC}{D}} = F\sqrt{AR}; \tag{5}$$

in which the quantity R is the ratio of fuel costs C, to investment account D. The constant A is usually about 0·5; B is from 0·8 to unity.

The area of heating surface per pound of fuel burned is seen to vary as the square root of the working costs, inversely as the square root of the investment costs, and directly with the square root of the annual working time—this varying inversely as the preceding item, fifty per cent. more can be paid for extended heating surface, where working night and day throughout the year, than where working but ten hours a day. A doubled cost of fuel and wages would justify increase of size of boiler by one-half for a stated power, the waste of fuel consequent upon inadequate size being such as to make this double expense for boilers, and the resultant saving, a paying operation. Common values of R range between fifteen and twenty-five. Where power is required to be concentrated, and forced draught is resorted to, its value falls greatly - often to three or four—as in the locomotive and in some marine practice. The following table gives some of these values:

COMMERCIAL EFFICIENCY OF BOILERS.

RATIO OF AREAS OF HEATING AND GRATE SURFACES.

Values of S.

F	6	10	12	15	20	30	40	50
R								
25	21	35	42	52	70	105	140	175
16	17	28	34	42	56	84	112	140
9	12	21	24	32	42	63	84	105
4	8	14	16	21	28	42	56	70

From the above equations, we obtain

$$E\ max. = \frac{B\,E}{1 + \sqrt{\frac{A}{R}}} \tag{6}$$

The following are examples, in greater detail, of the application of the above:*

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* *Ibid.;* also *Manual of the Steam Engine*, vol. ii, chap. viii.

EXPENSE ON BOILER ACCOUNT AND MAXIMUM COMMERCIAL EFFICIENCY.

	STATIONARY.		MARINE.	
CASES.	*I.*	*II.*	*III.*	*IV.*
Class 1 (D).	*Cornish.*	*Tubular.*	*Tubular.*	*Tubular.*
Total annual cost of boiler per unit of S	$1 50	$2 00	$3 00	$2 00
Interest	09	12	15	12
Repairs and depreciation	15	20	45	30
Rent, insurance and miscellaneous	10	07	1 00	20
Total value of D	34	38	1 60	62
Class 2 (C).				
Fuel (@ $5 for I, II, IV; $4 for III) per unit of F	7 50	7 20	12 00	2 00
Transportation and storage	1 00	1 00	10 00	1 00
Attendance (variable cost)	—	50	50	—
Total	$8 50	$9 00	$22 50	$3 00
Value of $\frac{C}{D} = R$	25	23	14	5
Value of A	0·5	0·3	0·3	0·5
Value of $\sqrt{AR}$	3·5	2·7	2·0	1·6
Value of F	8	10	16	20
Value of $F\sqrt{AR} = S$	28	27	32	32
Value of $S \div F$	3·5	2·7	2·0	1·6

The engineer thus solves the most important problem in boiler design which may be thus enunciated: To determine the commercial efficiency of a steam boiler doing a fixed amount of work; or, given all variable expenses of boiler installation, maintenance and operation, to determine what proportion of heating surface to grate surface or fuel burned will give the required amount of power at least total cost.

A second commercial problem may sometimes be presented to the engineer: A steam boiler is in place and in operation; all constant expenses are known and all variable costs of maintenance and operation are determinable. The question arises, or may arise whenever additional steam is called for: How much can be obtained from the apparatus when driven to such an extent as to yield most steam per dollar of total cost of operation? The independent variable is now the quantity of fuel burned in the boiler, and this is, in the established equation, represented by F, the fuel burned per unit of area of grate. This problem is thus stated:

Given: All expenses, constant and variable, and the method of variation of the latter and the proportions of the boiler as actually constructed, to determine that rate of combustion which will make the commercial efficiency of the given plant a maximum.

For this case, let K represent total annual expense, which is constant,

$$\text{and let } k = \frac{K}{G}.$$

Then the total cost of maintenance will be

$$P' = k\,G + D\,G\,S + C\,F\,G, \tag{7}$$

and

$$y = \frac{P'}{W} = \frac{k + D\,S + C\,F}{E\,F}, \tag{8}$$

F being taken as the independent variable.

This becomes a minimum when

$$F_1 = \sqrt{\frac{k\,S + D\,S^2}{A\,C}}; \tag{9}$$

and

$$E\ max. = \frac{B\,E}{1 + A\sqrt{\frac{k + D\,S}{A\,C\,S}}} \tag{10}$$

The following cases illustrate this problem :

EXPENSES OF BOILER AND MAXIMUM ECONOMY OF PLANT.

	STATIONARY.		MARINE.	
Cases	*I.*	*II.*	*III.*	*IV.*
Cost of maintenance: D	\$0 34	\$0 58	\$0 88	\$0 62
Cost of operation: C	8 20	9 00	14 50	3 00
Cost of operation: K	30 00	25 00	10 50	10 00
For maximum fuel and work: F_1 .	16	13	17	21
For maximum efficiency, as before: F	8	10	16	20
$S \div F$:	1·8	2·1	1·9	1·6

Case No. 1 is that of a Cornish boiler; No. 2 that of a multitubular stationary boiler; No. 3 that of a sea-going, and No. 4 that of a yacht, as before.

It is seen that in all cases the weight of steam delivered from the boiler and the quantity of fuel burned at maximum commercial efficiency, for the case assumed, are less than where the boiler—once set and still capable of being forced to deliver more steam than originally proposed and calculated upon—is worked up to a maximum delivery per dollar of total expense.

"Maximum Commercial Efficiency of Boiler" and "Maximum Efficiency of a Given Plant" are, therefore, by no means identical conditions, and it will usually be found that when this maximum work can be put on the boiler, it might be done still more economically by a boiler specially designed, as in the first problem, to do the increased quantity of work; the conclusions from this fact being simply that economy dictates that as much steam-power as possible should be grouped into a single plant in order to diminish the proportional cost of the constant part of running expenses, *i. e.*, otherwise stated, there being given a certain necessary expenditure, invariable within certain limits with variation of size of boiler or of quantity of steam made, the larger the amount of work done without increasing this constant expense, the cheaper will the steam be made.

The larger the plant supervised by the engineer, the less the total cost per pound of steam made, other conditions of economy being unchanged.*

It will be noted that the variations above computed for F are much less than those for S; the second being compared with the first case. Also, the harder the boilers are driven, the more nearly do the solutions of the two cases approximate the same limiting values. For the cases last assumed, the quantity of fuel burned, at highest economy, to the square foot of heating surface, is seen to range from 1·5 to 3·5; in usual practice this value is observed to range, as actually obtained with customary proportions and rates of combustion, from two to five, and to be gradually rising, where, as in marine practice, concentration of power is becoming more and more imperative.

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* *Ibid.*

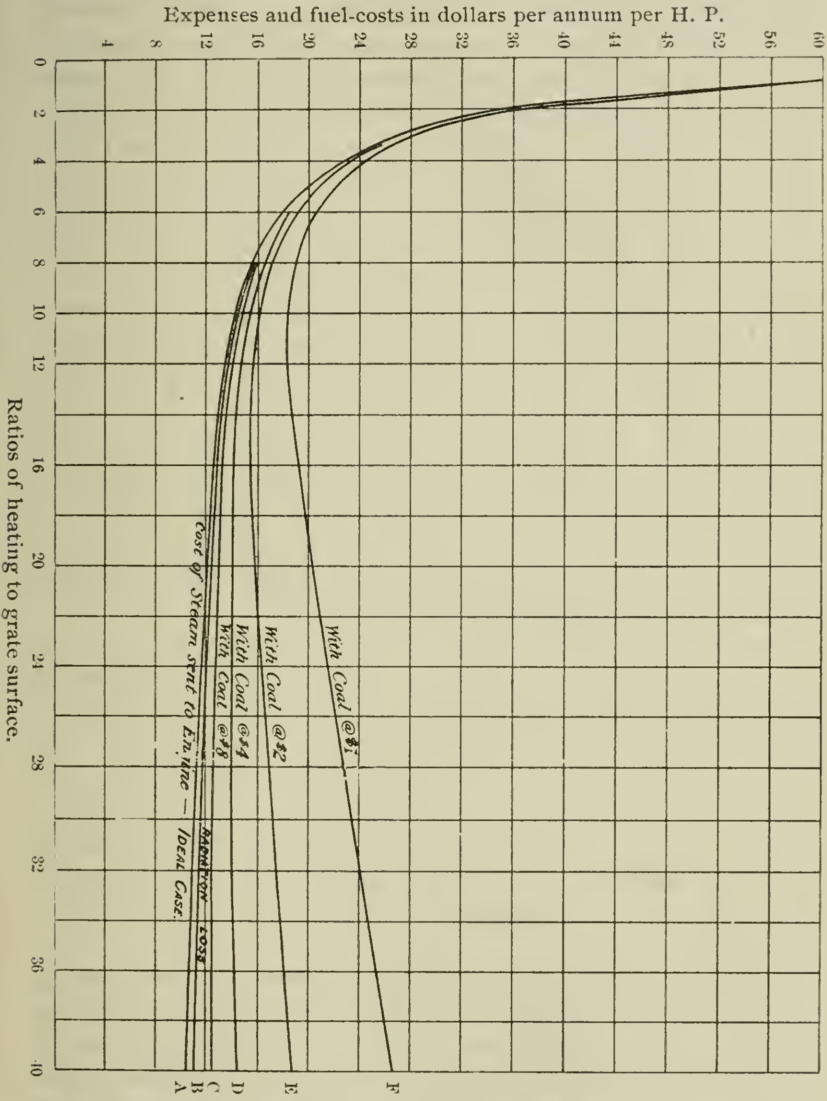

FIG. 1.—COMMERCIAL EFFICIENCY OF BOILERS.

A graphical construction may be readily made to exhibit to the eye the method of variation of costs with size of boiler. Thus, in *Fig. 1*, let it be assumed that the costs of fuel, simply, are those of purchase, supply, and use of 90,000 pounds of steam per annum, thirty pounds per hour per horse-power of engine; that the evaporation of this quantity of steam in a boiler of unity area of heating surface and equal grate area would compel the expenditure of twenty pounds of fuel per hour; that this fuel costs \$1.33⅓ per ton in the furnace; and that the period of operation is 3,000 hours. Let the ordinates of the curve represent the annual costs per horse-power in dollars, and the abscissas the necessary ratio of heating surface to grate area to give the required quantity of steam at the costs indicated by the value of corresponding ordinates. Then computing the relative costs with increasing areas of heating surface per unit of grate area, we obtain the curve marked "ideal case;" and the costs, for fuel simply, on the above basis, will decrease as indicated by that line. Costs of fuel thus rapidly decrease, with increasing areas of heating surface supplying the stated quantity of steam, until, at usual proportions, thirty to forty feet of heating surface to the foot of grate surface, the rate of combustion being reduced correspondingly, these expenditures fall from \$60 per annum per horse-power to \$10 or \$12.

But the costs of operation, outside the fuel account, must be added to obtain a measure of total costs. Let these be reckoned in terms of fuel costs and referred to the square foot of heating surface. Losses of heat occur, also, by conduction and radiation from boiler and connections, and *en route* to the engine; call these radiation losses and measure them in similar terms. Then the second line of the diagram will exhibit the costs of the horse-power, annually, when fuel and these wastes only are taken into account.

It is here assumed that the costs of operation, exclusive of fuel, will increase, so far as variable, with the area of heating surface, being proportional, nearly, to the cost of the boiler and to the interest account on that cost. Compute these costs, and take an equivalent value in fuel as the measure, per horse-power per annum, of the quantity to be added to the ordinates of the curve for such additional costs. We thus obtain the upper line of the diagram, on the assumption that the measure thus taken, ten per cent. on $4 per square foot of heating surface, corresponds to coal at $1 per ton. With increasing relative costs of fuel, the lines representing this, and the total costs of operation per horsepower per annum, fall lower and lower, as shown in the illustration, and the curve, which, in the first case, is seen to pass a minimum ordinate at between ten and twelve square feet of heating surface to the square foot of grate area, passes that minimum at higher and higher values of that ratio, until, at $8 to $10 per ton, the best proportions of boiler are found to be far beyond the limits of usual practice.

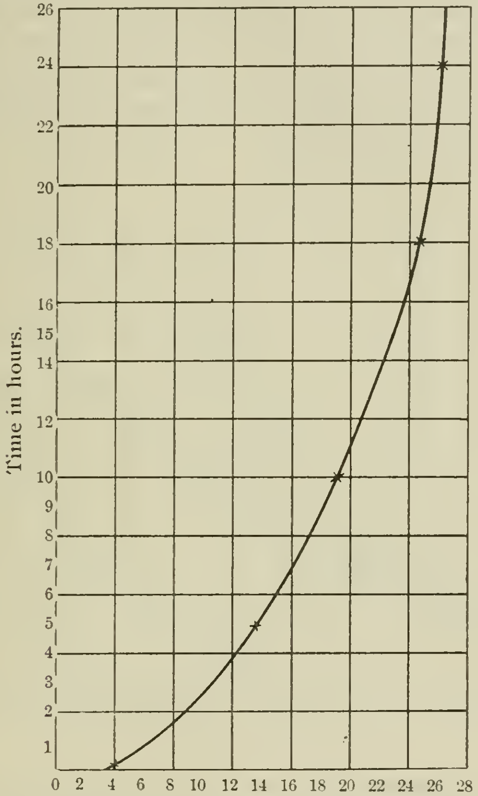

FIG. 2.—CURVE OF VARIATION OF "*S*"
Due to change in length of time of operation of the boiler.

The specially interesting fact illustrated by the diagram is the position of the best ratio of heating to grate surface in all common practice and at all usual prices of fuel and total costs. With coal at $1 per ton, we find this point which gives maximum returns for capital expended, at about 11 to 1; with coal at $2, it falls at 16; with fuel at $4 per ton, it comes in at the ratio 24 to 1. Assuming coal to cost $1 per ton, and labor to have half the value above taken, the line falls from *F* to *E*, giving the best ratio at 16; and with a value of labor and interest account at one-fourth that indicated by the line *F*, it drops to *D* while the best ratio rises to 24 and upward.

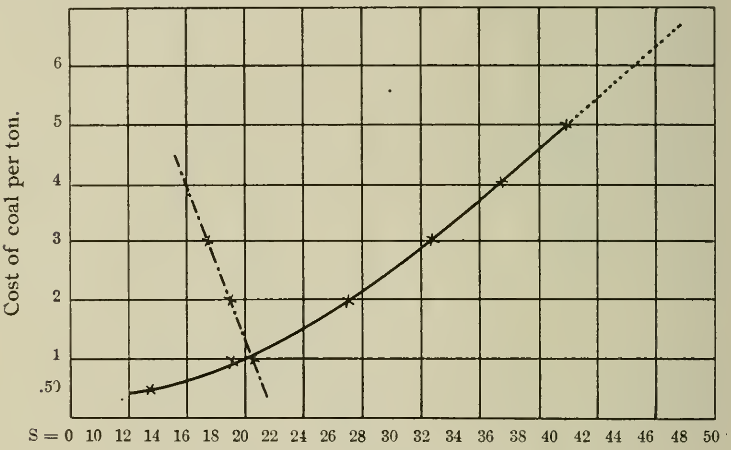

FIG. 3.—CURVE SHOWING VARIATIONS IN "*S*"
Due to changes in the price of coal. Changes in cost of labor shown by dotted line.

The next diagram, *Fig. 2*, exhibits the method of variation of the most economical proportions of boiler with change of time of working, through a range from an hour a day for the year up to continuous operation, night and day. The cost of fuel is assumed for convenience at $1 per ton and wages at $600 per year. Feed-water is taken as supplied at 185° F., and the rate of combustion as ten pounds per hour on the square foot of grate. The boiler is of 100 horse-power rated capacity, and capable, as is assumed, of supplying 3,000 pounds of steam per hour. The interest and other investment accounts, *D*, amount to forty cents per square foot of heating surface; the fuel account, *C*, with its incidentals,

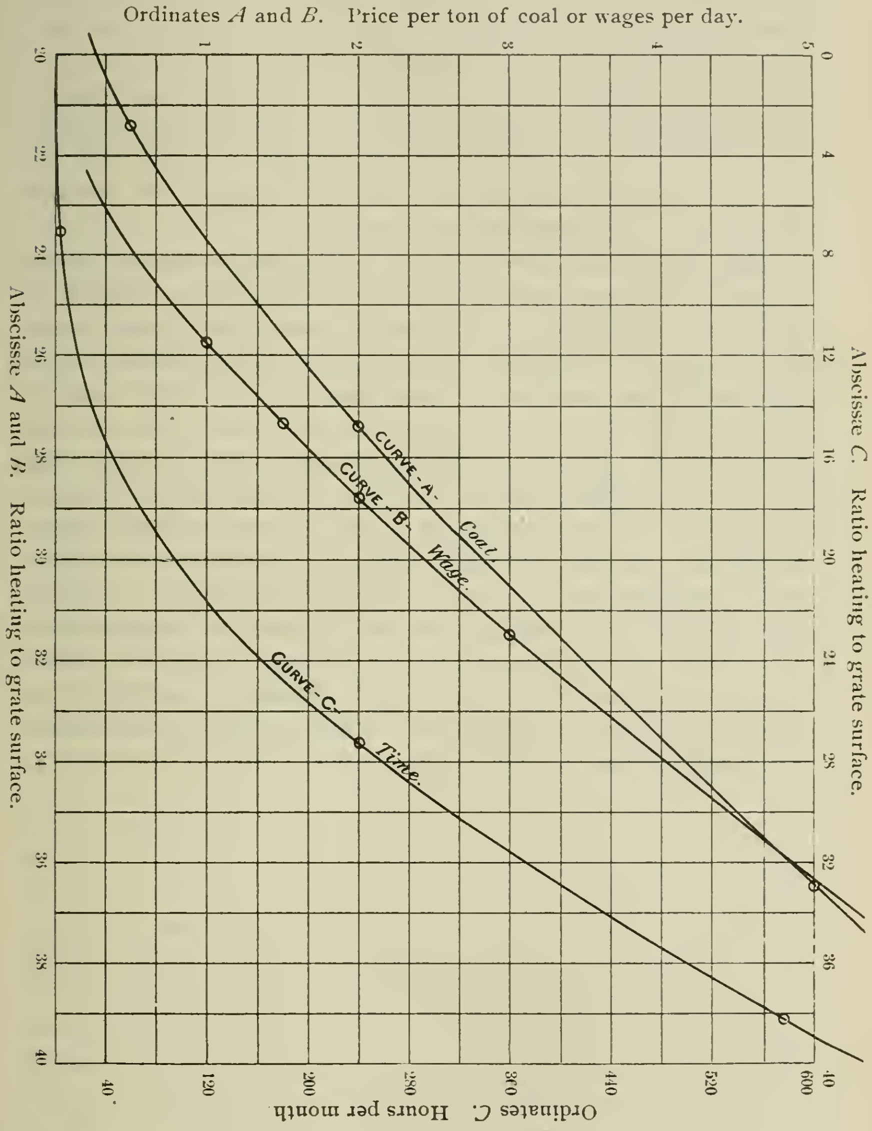

FIG. 4.—COST AND TIME VARIATIONS.

to $15. The regular working time taken as the basis of comparison is ten hours per day. At twenty-four hours working time per day, C becomes about \$35 and D about fifty cents. Points are thus worked out in the diagram and the curve drawn through them with the result here seen. Similarly, the diagram, *Fig. 3*, exhibits the variation in costs of fuel and of labor, and their influence upon the best proportions of boiler. The variations are taken as from a common point of departure, as above, which is assumed to be representative of a not unusual figure for fuel and for labor, at from \$1 to \$3 a day, where other costs are such as to give $S = 18$ when the figure is \$2.

The last set of curves, *Fig. 4*, exhibit still more fully the variations of proportions of boiler produced by variations of costs of fuel, wages, and time of operation, these costs being taken as ranging from one-half to five dollars per ton, and labor from one to five dollars a day. The time of operation varies between forty and six hundred hours per month, forty-eight to 7,200 hours per annum. Assuming fuel at \$2, wages at \$1.50, and 3,000 hours work per year, we find, for example, at these figures, taken as fairly representative of a very common practice, twenty-seven square feet of heating surface to the square foot of grate. It will be observed that, within the usual range of proportions, $S = 25$ to $S = 40$, the curves follow very nearly the paths of their tangents, and within this range of variation, we may take the size of boiler as variable directly with either fuel costs, wages, or time of operation without serious error.

THE EVOLUTION OF THE WORKSHOP.*

By C. John Hexamer.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Ladies and Gentlemen:

It may seem self-stultification to attempt the tracing of man's industrial progress in a single lecture. My apology is that a hasty review of the subject may stimulate thought and possibly lead some of you to take up a special department, which may ultimately be conducive of original research. Frequently, where minutiæ fail a broad generalization may be useful. The way in the forest is cleared by the axe, not by the razor. On visiting a strange town we first ascend an eminence, from which a general view of the topography may be obtained, thus gaining a clearer impression than by planlessly traversing the manifold ramifications of streets and by-ways. Even in literature the value of reading "in one sitting" has been advanced. The period of "drum and trumpet history" is passed. What we wish to know of a people is the economic conditions under which its members lived, labored and enjoyed themselves. Any light which you may shed on the history and progress of your own occupation is of great inherent interest and may prove valuable material on which others can build. Social and industrial customs are constantly undergoing infinitesimal changes, and, as the biologist discovers remnants of developments valuable in previous forms of life, but now useless and therefore disappearing, so the student of history, of sociology, or of economics, finds survivals and customs which have long since outlived their spheres of usefulness. Why do we, when mourning, wear black and the Chinese white? Most persons would say that we wear such garments as a sign of respect to the deceased, but this was not originally the case. The custom is a survival of the time when such dress was worn to indicate the "uncleanness" which was popularly associated with death and the grave. The early Aryan Nature Worshippers in Greece armed their dead warriors with a sharp sword, as they believed they would need it in the other world. When this belief died out, the custom survived in a debased form, and a little gilded sham sword was placed with the dead.

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* A lecture delivered before the Franklin Institute, December 8, 1893.

Aristotle has called man "a social (political) animal." "*A working animal*" might be a more appropriate term, for without labor and the creation of values, true happiness and social intercourse are impossible. Man was originally a "jack of all trades," necessarily forced to supply all his own wants. With the rise of his social position and the development of organization in the race his activity became more intense and its field less extensive. In other words, the higher his social position, the greater became the subdivision of labor, and the more of a specialist did be become.

When and where man first appeared on earth is a much disputed problem. Where authorities disagree by hundreds of thousands of years, it is idle for the layman to speculate. I prefer to follow Dr. Daniel G. Brinton, the eminent Philadelphia anthropologist, who is not an extremist in his views. The earliest deposit in which man's remains are found is that called the "drift," a series of gravel beds found in the valleys of the Thames, the Somme and the Manzanares. In these beds, stone tools and weapons have been discovered, lying in their original relative positions with the bones of animals long since extinct, and which could not exist in those localities under our present climatic conditions. After the warm period in which these animals lived, one of extreme cold followed, which man, however, weathered. Huge glaciers covered Scotland, Scandinavia and Switzerland; the forests of France were the haunts of Arctic quadrupeds, such as the reindeer, the white fox, etc.

Dr. Brinton estimates the period thus consumed and the time requisite for primeval man to develop and to spread over the area in which he lived, at not less than about 50,000 years; while other writers of eminence have demanded

200,000 years to explain all these changes in climate, organic life, denudation and deposition, etc.

The races of men have, largely on philological grounds, been subdivided into Aryan, Semitic and Turanian. The latter is the general receptacle into which are placed all those peoples of which we know little or nothing. The most ancient records of civilized man are probably those found in Chaldea. The most recent excavations of Layard, Loftus and Ernest de Sarzec, the French consul to Bagdad, show that other mighty and highly civilized cities existed in Chaldea before Babylon flourished. From these the culture of Babylon and of Assyria, and in all probability that of Egypt, were derived. I will not venture to speculate as to the time requisite to bring this people up to the high state of culture in which, judging from archæological excavations, they must have been almost 4,000 years before our era. The earliest paleographic records we have are the mace-heads and seals of Sargon, of Agade, dating from 3800 B. C. The writing of this people, although yet distinctly linear, assumes the wedge shape, and the art of seal-making seems to have been in advance of the sculptures of the time. These ancient Chaldeans were acquainted with most of the useful arts; they were metal-workers, sculptors, weavers, etc. The art of music had been introduced, as is evident from representations of the harp, and of men with pipes and cymbals.

Although I should not like to go as far as those who boldly declare the Chaldaic origin of Egyptian civilization, if, in fact, I have a right to express any opinion on a subject in which I am not a specialist, I believe that the Egyptians, originally a hamitic people, were largely civilized by semitic immigrants, and that their culture and racial types were greatly altered by commingling with the semitic invaders. An authority on this subject has thus well summarized the present state of our knowledge on this subject: "For the present we must be content to say that in the remote period before the pyramid age, in the fifth millenium before our era, there was a sea communication between Chaldea, Punt, Egypt and Sinai, and an interchange of the elements of civilization. There is a convergence of the lines of origin of the two great civilizations of antiquity, but as yet their point of meeting is lost in the haze of the past."

It is, of course, exceedingly difficult to tell exactly what was the state of the people and of the workers of very ancient times. With caution, not driving analogies too far, we may learn something from the semi-barbaric tribes which we find in various states of progress at the present time. Fiske has well pointed out that the tribal forms of our American Indians have shed new light on the early tribal life of Greece and Rome. It is probable that the laborers of ancient Egypt were serfs, in condition not very different from the fellahs of the present day. Ebers relates how, when the statue of an ancient Egyptian overseer was brought to light, the native laborers at work immediately cried out: "It is our tax collector!" and it is probable that the Jews who had settled in lower Egypt were not more severely oppressed than the rest of the people. They had settled during the reign of the Hyksos, semitic invaders who ruled Egypt for a time, and when, by a national revolt, native princes were called to reign, special favors formerly granted the Jews were revoked.

In Assyria and Babylonia there seems to have been a system of slavery and of castes.

Another semitic people, the Phœnicians, were the great artisans of antiquity. They built the temple for the Jews, and were akin to them in blood and in speech. From them the Greeks first acquired the arts, as is well shown by the ancient myths of Cecrops, Danaus, Cadmus, etc. Even the Greek religion, an Aryan nature-worship, was largely influenced by them; thus Hercules was a transformed Melcarth, Aphrodite an Ashtoreth. Unfortunately, almost all records of the Phœnicians are lost, and all that we know of their great colony, Carthage, is what we have received from their implacable enemies, the Romans.

With the Greeks the ideal of beauty was born into the world. Their great maxim, "Nothing too much," guided them in everything and made them masters of absolute proportion in art, architecture and literature. Their daily life we know comparatively well. Most of their work was carried on by slaves. In conceiving of the condition of the slaves, we must, however, disimbue our minds of the modern idea of slavery. These slaves were frequently highly cultured persons, who taught the children of their masters. Thus our word pedagogue is taken from pedagogos, originally an old slave employed to take children to school. Mahaffy tells us that the average price of a slave, calculated in our money, was $40, and that of a horse $60. The free Greek believed manual labor degrading, and the poor Athenian, rather than work, would serve on a jury and live on a few cents a day. Work was left to slaves and aliens. The ancient Greeks divided their property into two classes, the visible and the invisible. The great *entrepreneur* or speculator was honored, but bargaining was looked upon as a species of cheating, and was carried on almost exclusively by aliens. The rate of interest was 12 per cent.

Among the Romans we find a similar state of affairs, the work being left to slaves and freedmen (slaves set free). With them we find, for the first time, a sort of guilds; for the chapters, which long were looked upon as a species of our secret societies, seem to have been trade guilds. To Rome we owe the conceptions of law, order and civics. They gave us the contract, that great boon of the weak and poor, through which, by combining, they can compete, as incorporated bodies with the rich and powerful. Rome committed moral suicide. One of the Church fathers tells of a woman who danced on the grave of her twenty-sixth husband, she having been the sixteenth wife of the deceased. Ethical debasement was followed by physical weakness, and Rome died for want of men. When the Germanic tribes broke into Italy they found it an empty egg-shell, readily crushed. We must be careful not to form our ideas of ancient life from plays and novels, except those written by eminent historical authorities, and these, *en parenthèse*, are frequently not of high literary value. Thus, the people in Shakespeare's "Julius Cæsar" are not Romans and do not talk like Romans. They are the shoemakers, tailors, etc., of the time of Elizabeth, when Shakespeare wrote. This, of course, does not detract from the high standard of the play as a literary production.

It was destined that the Teutons should infuse new blood into decrepit Rome and ultimately hand down the ancient civilization in its present form. In order to readily collect taxes the government in later Rome bound the tillers to the soil, and we can understand the evolution of serfdom only by studying these conditions. These semi-serfs were protected by the army, which was largely made up of Germanic mercenaries. The usual Teutonic tribal form was: (1) A king, duke or leader; (2) the Council of wise men or elders; and (3) the General Assembly of the people, which last has survived, in one form or another, in the make-up of the executive and legislative bodies of to-day. When the Goths had conquered Rome, they formed the fighting or protecting class, and for this protection they exacted taxes and allegiance. From this system of allegiances feudalism slowly grew. After the Germanic tribes, the Angles, Saxons and Jutes, had conquered England, they brought with them their Teutonic usages, and when later they settled in towns we find the town council a feature which is still preserved in our New England town meeting. The chief was the Reeve, and when representative government was installed, a Reeve had to be chosen for the Shire. He was called the "Shire Reeve," a term from which our word "Sheriff" is derived. The Shires of England, it should be explained, were at one time independent kingdoms. By the conquest of the Normans (a Scandinavian-Teutonic race which for a time had settled in Normandy) things were slightly changed, and a Town or Thorpe (the German Dorf) assumed this form. There was the manor, with, first, the lord of the manor, usually a Norman, the village tract of cultivated ground around it; and the commons, composed of fallow lands and woods. In parts of Germany this is still found in the modified forms of the Gemeinde Wald and Gemeinde Wiese. Thus lived nine-tenths of the people in England. By the fifteenth century the serfs had become free in England. Serfdom lingered on much longer in Germany, giving rise to endless trouble, such as the terrible revolt of the peasants at Rothenburg-on-the-Tauber.

After the restoration of order, and when the general shaking-up caused by the migrations of the Teutonic races had subsided, and when walled cities had arisen to give protection to tradesmen and merchants, these classes united, for mutual protection, into guilds. These guilds in many cases became the real town governments, entering into agreements with the guilds of other cities and even with those of foreign countries. The emperors and kings, early recognizing in these guilds powerful allies against the haughty and unruly nobles of their realms, were anxious to extend to them their patronage. Thus were evolved the mighty leagues of the cities on the Rhine—the Free Cities and the Hanseatic League (with its own emporium in London at the steel yards) which could successfully cope with the most powerful princes of the time. Later the craft-guilds originated, in which various workmen of a certain trade united, such as the weavers, fullers, armorers, cutlers, bakers, and crafts which are no longer practised, such as the fletchers (makers of arrows) and bowyers (makers of bows). In London the guild of the goldsmiths became of great value to the world at large. They issued certificates on bullion deposited, and gave additional credit for such deposits, introducing thereby our present system of banking, known as the English system. The statement which is often made, that the bank of Amsterdam originated our system of banking, is erroneous. This bank issued certificates for the amount on deposit only. The guilds were true monopolies. They were beneficial, providing a common fund for the sick, for the aged, and for widows and orphans. They assisted members of their fraternity who fell behind in their contracts, and celebrated the annual feast of their patrons, for each craft had its own special patron saint. They regulated manufacture and prevented all competition, and were thus largely economic in their functions. Ben Akiba has well said, "there is nothing new under the sun," and many now make propaganda for a "new" theory, not essentially different from the one then in vogue. Everything moved in prescribed ruts. Every countryman was a member of a town community. Every merchant and mechanic was a member of a guild. In some cities art guilds were formed, such as the *Meistersänger*, who carried on poetry and music by absolute rule of thumb. Of all the prodigious quantity of so-called "poetry" produced under these conditions, but a few gems by Hans Sachs now retain value. The rest is rubbish.

But the mediæval system was to disappear and the ice-bound world of custom was to be broken up by the springtide of revivifying thought and learning. The period known as the re-birth (renaissance) had come. Through the study of the methods of the ancients, of their mode of thinking, their philosophy, their literature and art, new literatures and new periods of art arose. The fall of the Greek Empire, in 1453, drove many Greeks into Europe, and this also had some influence on the intellectual awakening, although by no means so decisive a one as is frequently ascribed to it in text-books. The invention of gunpowder enabled the physically weak man to successfully cope with an armor-clad giant on horseback, and to destroy the walled castles of the knights. The art of printing rapidly spread the "new learning." The introduction of the compass opened a new era to navigation and exploration. Lastly, the fall of the mediæval church removed the shackles that had bound free thought. In the towns of Flanders, arts and manufactures flourished, and, under the greater security of free protected cities, gave rise to more liberal institutions and to greater freedom of speculation. The validity of the inscription on the peristyle of our World's Fair, "Ye shall know the truth, and the truth shall make you free," is borne out by history. With the increase of manufactures in Flanders, a reflex action was noticeable in England. The latter country had been a great grain-producer, but with increased remuneration for its excellent wool, which was in great demand on the other side of the channel, an extension of sheep-raising, and, *pari passu*, the enclosure of commons and the consolidation of small holdings followed. When, through subsequent oppression, many liberal Hollanders emigrated to England, they introduced and taught the art of weaving and working woollen goods, creating a still greater demand for large sheep farms. The villagers or small farmers were gotten rid of by ignoring the old traditional security of tenure, by confiscating commons and by raising rents. Wherever tenants failed to perform all the conditions of their leases they were ejected, and expiring leases were not renewed. Violence and the bribing of legislative and judicial bodies were also brought into play, and were then much easier than now; for even the contemporaries of Henry VIII when he wished to find a pretext for the judicial murder of Sir Thomas More, and therefore preferred charges of venality against him, were much surprised when the trial proved that the Chief Justice had never received presents from litigants, as was then a common custom.

In these various ways the small farms were depopulated. The ancient holdings and claims of the thorpes were denied, and the inhabitants of the villages were scattered to the winds by reason of the changes in the economic conditions. Those who had formerly been prosperous small farmers became laborers on large farms, others were retained as helpers on sheep farms, and only the more fortunate and intelligent became large farmers. But many found themselves members of a starving peasantry, vagabonds and sturdy beggars (although begging was by statute made a crime), and finally many became paupers and criminals in the towns. The former lords of manors became great landlords, of whom the large farmers rented their lands; and only farm laborers occupied the old villages.

In towns, the guilds were destined to be broken up. Whenever a number of persons are banded together to advance a monopoly, they are sure, fortunately for mankind, sooner or later to hang themselves in their own rope. The guilds had become very exclusive; allowing special privileges to the sons and sons-in-law of members, charging excessive entrance fees, and increasing the time of service and other requirements of apprenticeship, while the increase in the capital necessary for engaging in business made it more difficult for journeymen to become masters.

In the sixteenth century a class of capitalists, merchants, arose, known as "clothiers." These set spinners and weavers to work in the cottages of country villages, furnishing the raw material and paying a fee for the labor expended. This was the final death-knell to the guilds, the remains of which exist in our own time only as narrow aristocratic bodies. Carpenters' Hall, in our own city, is the historic remnant of a guild.

By the middle of the eighteenth century the towns had lost their supremacy in manufacturing. Cheaper living was to be had in the country, and weaving was carried on in combination with agriculture. But by 1750 a change in England had become imminent. The population of the country, which, at the time of Elizabeth, was only 5,000,000, had grown rapidly. Her colonies consumed large quantities of goods, and there was a demand for more rapid production, while capital had accumulated, and was anxiously awaiting the opportunity for investment. In 1761, the English Society of Arts offered two prizes, of fifty and twenty-five pounds respectively, for the best, and the second best, invention for spinning six threads by one person; but the devices submitted were not practical.

The *Era of Invention* was however soon to dawn upon the world. In 1764, Hargreave invented the "spinning jenny," by which first eight, then twelve, then twenty, and ultimately a hundred threads were spun at a time. The secrecy in which this invention was at first shrouded was soon divulged, and in less than a dozen years the jenny was in general use. In 1768, Arkwright gave to the world the "water frame." Crompton invented "the mule" in 1776, combining the advantages of the jenny and of the water frame. Rapid improvements in carding machinery followed. Cartwright's "power loom" was invented in 1784, and improved in 1787, and was universally in use by 1800. In 1792 our great American inventor, Josiah Whitney, gave to the world the cotton-gin. There was now a pressing need for greater and more reliable power to drive machinery. Watt improved the steam engine in 1769; and in 1785, one of the most important dates in history, the steam engine was first used to furnish power to a cotton mill. This broke up the system then in use. Special factory buildings of greater size had to be constructed, and these were now located near fuel supplies, and where raw materials and products could be more readily handled; the details of manufacture became more complex, greater capital was requisite for a manufacturing enterprise, and its management necessitated greater executive and business ability. The prices of goods were rapidly lowered by the enormous increase in production, but the introduction of more advantageous methods of manufacture nevertheless permitted the rapid accumulation of great fortunes. The great *entrepreneurs* became a new aristocracy, that of money.

There was now a seething wave of humanity, from the country to the towns, the reflex of that which had once set in from the towns to the country. Forced by additional enclosure acts, the poorer country population swarmed to the factory towns, and England became, as has been well said, "a great industrial organization, where everything was done on a large scale and the world was her market." In this great workshop, the laboring population, having lost its hold on land, on capital, and on the direction of the enterprise, was cut adrift. The great masses of the population were mill-hands, and practically the slaves of employers. There were then no associations and trade unions, and deplorable conditions existed. Wages were low and hours extremely long; women and children were worked beyond physical endurance, and their habitations were those of squalid misery. I will not dilate on the sickening details of physical and moral debasement of "the sweating systems" of those times, when children, in order that manufacturers might procure still cheaper labor, were apprenticed from almshouses.

The world was then laboring under a most inhuman economic system. The "*laissez faire*" doctrine was carried into practice, with its appendages, the theories of the "wage fund" and of the "iron law of wages," teaching that there is in each country a certain amount of money to pay wages, and that if the population increases, there must be a corresponding decrease in wages until a sufficient number perish to restore wages to a living standard for the remainder.

As is so frequently the case, help was not to come from educated theorists, but from the sound common sense of the middle classes. Amidst the tremendous opposition of manufacturers and of disinterested political economists and their followers, who declared that the government had no right to interfere, the first factory act was passed in 1802. Its interference was exceedingly mild, its enactments being limited to such trivial requirements as those providing for the ventilation and whitewashing of factories, stipulating two suits of clothes annually for "bound children," and limiting the working day of these unfortunates to twelve hours, Again, the exertions of the sound-minded middle classes. secured, in 1833, the appointment of a parliamentary commission, whose report was followed by an act which stipulated that no children under nine years should be employed; that those between nine and thirteen years of age should not be worked more than eight hours, and those between thirteen and eighteen not more than eleven hours each day, and that boys under twenty-one and women should not be put on night work.

Slowly the *Era of Trade Unions and Socialism* came into being. Laborers began to recognize their community of interest, and attempted to unite, but an act of 1799 made it a crime for them to combine for an increase of wages, or a decrease of working hours, or to persuade others to leave work; and it was not until 1875, after a number of previous ameliorating acts had been passed, that the last remnant of illegality was removed from such combinations. It is unnecessary for me to dwell on the phases of the struggle in our own country, the several State acts, labor commissions, etc. At present, Australia, to which we owe so many reforms, is attempting to evolve a practical system of arbitration. The weapons wherewith capital and labor have been combatting are the "strike" and the "boycott" on the one side, the "black-list" and the "lockout" on the other. These, however, are too well known to require detailed description here. It is noticeable that both sides are becoming more moderate in their views, and that their disputes are becoming less acrimonious. Labor unions act like double-edged swords. Restricting, as they do, individual freedom of action, their members must necessarily sacrifice some of their personal freedom. But human social progress has been in the same direction. As citizens of a State and of a community, each of us gives up certain individual rights for the general welfare. We are slowly recognizing the equity of State interference, notwithstanding the trumpet blasts of such ingenious theorists as Herbert Spencer.

Brushing aside feudal aristocracy, which is practically effete, though still lingering on in parts of Europe, and the adoration of American heiresses, we may, for practical purposes, divide humanity into three classes: the capitalist or money-lender, who receives interest; those who build and operate mills, keep stores, manage, receive profits, etc.; and those who do daily work and receive wages. It has been attempted to unite these functions by a system of co-operation, as in the experiment of the Rochdale Pioneers in 1844, when twenty-eight workmen each subscribed $5, agreeing to buy only at the co-operative store. In 1882, there were 1,268 such stores with 650,000 members, and it is stated, on reliable authority, that in Northwestern England, one-fourth of the population buys its supplies from co-operative stores. Another experiment was that of the Minneapolis coopers. In 1874, sixteen of these coopers contributed $15 each, and established a shop of their own, dividing the profits. Leclaire, a Paris painter, in 1842 began the system of sharing profits with employés, who had been long in his employ. The Oxford Building Association was an attempt to stimulate thrift, and extended its example, in 1831, to the United States, and the plan has proved astonishingly successful in our city of homes. Great competition has also called into being combinations of manufacturers, known as "trusts."

In recapitulating these successive steps of combinations, accompanied by limitations of the personal rights of individuals, we cannot forbear asking the question: Are we drifting toward socialism? This is a proposal to abolish competition and individualism, substituting for them some form of government or social control over land, capital, management, distribution and labor. It opposes competition, rent for land, interest on capital, computed profits and the individualistic ideal of society. In other words, each individual works for the community instead of for himself, and each one receives from the community and not from other individuals or corporations. Wherever the system has been tried practically it has proved a failure. In early colonial times in this country, we find it wrought starvation. In Russia the great famines are the direct outcome of the communistic system of the Mir.

Louis Blanc is the originator of that form of modern socialism which is opposed to the radical measures formerly advocated, and proposes the utilization of present governments to commence reforms, and thus gradually to lead to socialism. (Another form emanating from the brains of poets and visionaries has given rise to what is known as Nationalism.)

It would be idle to speculate on what we shall ultimately reach, but I think it is safe to say that we are tending toward government ownership of railroads, the telegraph and telephone lines and all municipal necessities. In Germany, a great statesman, Bismarck, has introduced compulsory insurance.

After tracing thus rapidly human industrial progress from the most ancient times to the present, we cannot more aptly close than by asking and attempting to answer the question: *What is the present status of the evolution of the workshop?* Competition has broken down in many lines of practical business, and trust combinations of all sorts flourish, notwithstanding the opposition of statutes, courts and public opinion. Even violent measures, such as reductions of tariff, free trade, etc., prove of no avail, as powerful trusts are better able to successfully meet foreign competition than small business concerns fighting single-handed. The *raison d'être* of trades unions is now generally recognized, and they are encouraged. Co-operative efforts have been in part successful and are still on trial; and factory laws have been enacted in all civilized countries.

We have no reason to fear the future. Extremists may prove temporarily obnoxious, but will not prevail in the end. They may, indeed, do good, as the happy mean is found between the extreme pendulum-swings of human thought. These problems will be solved, as all human progress has been accomplished, by infinitesimal changes directed by economic conditions. Nor need we dread the increase of population, for history and sound economics clearly teach us that such fear is groundless, and have established the grand ethical axiom, that bed-rock of human experience on which we can safely build, that in the end right and truth will prevail.

A THEORY OF THE ACTUAL EARTH PRESSURE AND ITS APPLICATION TO FOUR PARTICULAR CASES.

By P. Vedel, C.E., M. West. Soc. Eng.

[*Concluded from p. 148.*]

In these expressions θ everywhere is to be taken positive or negative according as φ is positive or negative.

Is $R = o$, *i. e.*, the cylinder an infinitely thin rod, then (11) gives

$$F = \begin{cases} o \\ \frac{1}{3}\pi\gamma H^3 \dfrac{cot.^2 \beta .\ sin\,(\beta - \varphi)}{cos\,(\beta - \varphi - \varphi')} \end{cases}$$

according as the earth is

$$\begin{cases} \text{inside} \\ \text{outside} \end{cases}$$

the cylinder. For the first case (13) gives $\beta = 90°$. For the latter case (12) gives

$$cot\ \beta = \tfrac{1}{2}\ cot\ \varphi . \frac{sin\ \theta\ (1 - 4\ sin\ \theta)}{(1 + sin\ \theta)\ (1 - 2\ sin\ \theta)}$$

as an approximation, whereas by returning to (8) we find the exact solution

$$cot\ \beta = \frac{1 - 4\ sin^2\ \theta \pm \sqrt{1 + 8\ sin^2\ \theta}}{4\ cos^2\ \theta\ tg\ \varphi}$$

This value of *cot β*, therefore, will make *F* a maximum or minimum, or, by (11),

$$F\frac{max.}{min.} = \frac{\pi\ \gamma\ H^3\ cos^2\ \varphi'}{24\ sin\ \varphi.\ cos^3\ (\varphi + \varphi')}\left[1 - 20\ sin^2\ \theta - 8\ sin^4\ \theta \pm (1 + 8\ sin^2\ \theta)^{\frac{3}{2}}\right] \qquad (14)$$

the upper sign corresponding to φ positive and the lower to φ negative.

The four particular cases enunciated above must now be considered separately. In the first case, when the bottom sinks a little, a right circular cone or frustum of a cone of earth described over its circumference will follow it, and the balance of the earth, retained by the wall friction, will slide down along the cylindrical surface and, relatively, upwards along the conical surface. Hence, φ is negative, φ' positive, or the pressure on the cylinder is what we have called passive-active.

In the second case, when the bottom is lifted a little, a right circular cone or a frustum of a cone of earth is lifted with it, and the earth which has been retained by the wall friction will also be lifted, sliding up along the cylindrical surface and, relatively, down along the conical surface. Consequently φ is positive, φ' negative, or the pressure on the cylinder is what above was called active-passive.

In the third case, when the cylinder is pushed down a little, the surrounding earth contained between the cylindrical surface and a frustum of a right cone described over the bottom and with its apex turned downwards will be lifted, sliding upwards along the cylindrical and conical surfaces. Hence φ is negative, as is φ' also. The pressure on the cylinder therefore is passive.

In the fourth case, finally, when the cylinder is pulled up a little, the surrounding earth contained between the cylindrical and the truncated conical surface will slide downwards along both surfaces. Hence, φ is positive, as is φ' also, and the pressure on the cylinder is active.

All possible kinds of earth pressure are, therefore, represented by these four cases.

Returning now particularly to the first of them, we have by (11) the weight, W, carried by the bottom:

$$W = \pi\gamma R^2 H - F = \pi\gamma R H \left[R - CH\left(1 - \frac{H}{3R} \cot. \beta + A\right)\right] \quad (15)$$

where

$$C = \frac{cot\ \beta .\ sin\ (\beta + \varphi)}{cos\ (\beta + \varphi - \varphi')}$$

and A is the same as above. The maximum of weight, W, which may have to be carried, will correspond to a minimum of F or the value of β determined by (12) or (13).

For a given constant value of β, W will from O, corresponding to $H = o$, increase with H until for

$$H = R\ tg\ \beta \left(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}}\right)$$

if $C\ tg\ \beta > 1$, it reaches a maximum

$$W = \tfrac{1}{3}\pi\gamma R^3\ tg\ \beta \left[1 + 2\,(1 - C\ tg\ \beta)\left(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}}\right)\right].$$

It will then decrease until for $H = R\ tg\ \beta$ it is:

$$W = \pi\gamma R^3\ tg\ \beta\ (1 - \tfrac{2}{3}\ C\ tg\ \beta).$$

For $H > R\ tg\ \beta$ will A be a positive quantity and

$$W = \pi\gamma R^2 \left(H - C\,H\ tg\ \beta + \frac{C\,R}{3}\ tg^2\ \beta\right)$$

which, if $C\ tg\ \beta > 1$, will decrease indefinitely until for $H = \infty$ it is $W = -\infty$. If, on the contrary, $C\ tg\ \beta < 1$, then W will have no maximum, but increases continually when H increases from $H = o$ to $H = R\ tg\ \beta$, and from $H = R\ tg\ \beta$ to $H = \infty$, when $W = \infty$.

Theoretically, therefore, the weight on the bottom can decrease to nothing or even to a negative quantity, which means that a load could rest on the surface of the ground without exerting any pressure on the bottom.

Differentiating equation (15), denoting by $\pm \pi \gamma x^2$ the ratio of variation,

$$\frac{d\ W}{d\ H}$$

and transforming for $H < R\ tg\ \beta$ to

$$C\,(H - R\ tg\ \beta)^2 \mp x^2\ tg\ \beta = R^2\ tg\ \beta\,(C\ tg\ \beta - 1) \qquad (16)$$

and for $H > R\ tg\ \beta$ to

$$\pm\, x^2 = R^2\,(C\ tg\ \beta - 1) \qquad (17)$$

we find the weight carried by the bottom represented by an earth body described as follows: If $C\ tg\ \beta > 1$ it will for values of

$$H < R\ tg\ \beta \left(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}}\right)$$

be the volume intercepted between the bottom and the upper surface of the earth of a body of revolution formed by revolving the lower half of the hyperbola (16), taken with its upper sign, around the axis of the vessel;

for $$H > R\ tg\ \beta \left(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}}\right)$$

but $< R\ tg\ \beta$ it is the whole volume above the bottom of the lower half of the hyperboloid less a volume intercepted by the upper surface of the earth of an ellipsoid, of revolution formed by revolving the ellipse (16), taken with its lower sign, around the axis of the vessel; for $H > R\ tg\ \beta$ it is the volume above the bottom of the lower half of the hyperboloid less the half of the ellipsoid and less a volume intercepted of the right vertical cylinder (17), taken with the upper sign, between the upper surface of the earth and a horizontal plane the distance of which from the bottom is $R\ tg\ \beta$. If, on the contrary, $C\ tg\ \beta < 1$ it will for $H < R\ tg\ \beta$ be the volume intercepted between the bottom and the upper surface by a body of revolution formed by revolving the lower half of the hyperbola (16), taken with its upper sign, around the axis of the vessel, which is the imaginary axis of the hyperbola; whereas for $H > R\ tg\ \beta$ it is the volume above the bottom of the lower half of the hyperboloid plus a volume intercepted of the right vertical cylinder (17), taken with the lower sign, between the upper surface of the earth and a horizontal plane, the distance of which from the bottom is $R\ tg\ \beta$. If, particularly, $C\ tg\ \beta = 1$ the weight will for all values of $H > R\ tg\ \beta$ be represented by a cone described over the circumference of the bottom with a height $H = R\ tg\ \beta$, and for $H < R\ tg\ \beta$ by a frustum of this cone.

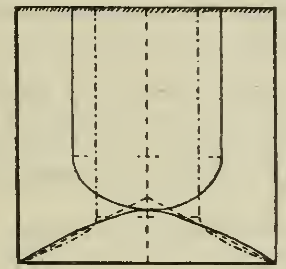

FIG. 2.

The annexed diagram, *Fig.* 2, represents the three cases for $\varphi = 30°$, $\varphi' = 25°$ and β either 40°, 27° 30′, or 20°.

In the second of the four considered problems the force to be exerted on the bottom is by (11):

$$W = \pi \gamma R^2 H + F = \pi \gamma R H [R + C H (1 - \frac{H}{3\ R} cot\ \beta + A)] \quad (18)$$

where
$$C = \frac{cot\ \beta\ sin\ (\beta - \varphi)}{cos\ (\beta - \varphi + \varphi')}$$

The maximum force will correspond to a maximum of F or the value of β determined by (12) or (13). For a given constant value of β, W will from O, corresponding to $H = o$, increase with H until for $H = R\ tg\ \beta$ it is:

$$W = \pi\ \gamma\ R^3\ tg\ \beta\ (1 + \tfrac{2}{3}\ C\ tg\ \beta)$$

and from there indefinitely until for $H = \infty$ it is $W = \infty$.

Differentiating equation (18), denoting by $+ \pi \gamma x^2$ the ratio of variation

$$\frac{d W}{d H}$$

and transforming for $H < R \, tg \, \beta$ to

$$C (H - R \, tg \, \beta)^2 + x^2 \, tg \, \beta = R^2 \, tg \, \beta \, (C \, tg \, \beta + 1) \text{ and } \quad (19)$$

for $H > R \, tg \, \beta$ to

$$x^2 = R^2 (C \, tg \, \beta + 1) \quad (20)$$

we find the weight geometrically represented, as above, by a part of an ellipsoid of revolution and a cylinder. *Fig. 3* corresponds to values

$$\varphi = 30°, \varphi' = 25°, \beta = 40°$$

Considering next the third of our four problems, it is evident that the weight which will push the cylinder down must equal the friction on the cylindrical surface plus the counter-pressure of the earth against the bottom. But it is difficult to ascertain how great this latter is. A merely vertical pressure will give the earth only a very slight tendency to move out to the sides, as we know from the experiment with U-shaped glasses, in the horizontal branch of which sand filled in one of the vertical branches will hardly advance any. And escape the earth must, for its compressibility is only very limited; in fact, a system of loose particles without friction or cohesion will, as proved experimentally by Reynolds (*Nature*, vol. xxxiii, 1886), by itself assume its greatest density or least volume, and hence

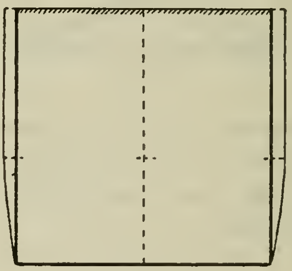

FIG. 3.

expand by any rearrangement of the particles caused by pressure or otherwise. If a pointed pile is being driven, an earth body intercepted around the conical point by another cone with the same apex will slide upwards along the surfaces of the two cones. The cylindrical part of the pile will press this earth body outward, and the resistance of the surrounding earth will cause it to move upwards. Thus the whole earth body around the cylindrical surface of the pile, limited by the truncated conical sliding surface down to the depth of the apex of the point, will be lifted a distance, dy, determined by the volume of earth, $\pi R^2 dz$, driven out by the pile going down a distance, dz. W being the weight on the pile, F the friction on the cylindrical surface, $H + h$ the depth down to the apex of the point, β, as before, the angle of inclination of the sliding surface, then we shall have

$$W\,dz = F\,dz + \tfrac{1}{3}\pi\,\gamma\,\frac{\cos\varphi'}{\cos(\beta+\varphi+\varphi')}(H+h)^2\cot\beta$$

$$[(H+h)\cot\beta + 3R]\,dy$$

where

$$\pi\,(H+h)\cot\beta\,[\,(H+h)\cot\beta + 2R]\,dy = \pi\,R^2\,dz$$

Hence

$$W = F + \tfrac{1}{3}\,\pi\,\gamma\,\frac{\cos\varphi'}{\cos(\beta+\varphi+\varphi')}\,R^2\,(H+h)$$

$$\left(1 + \frac{R}{(H+h)\cot\beta + 2R}\right)$$

When the pile is not pointed, as when we consider our cylindrical vessel, it may be supposed that the earth itself forms an earth point or earth cone under the bottom, and that this point then goes down ahead of the vessel pushing the other earth out to the sides.* If the vertical pressure shall make the earth slide upwards along the surface of this cone, the angle of inclination of its generatrices must, at least, equal the angle of friction or $h = R\,tg\,\varphi$. This angle of friction may, on account of the compression, be somewhat greater than elsewhere in the earth; but as these considerations lead, anyhow, only to approximations, we may take it the same as φ.

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* This supposition would agree well with the experience that piles with blunt ends are often driven quite as readily as pointed ones.

Representing now, approximately, the friction along the earth point by the friction on an additional height, h, of the cylindrical surface, we have by (11)

$$\begin{aligned} W = \frac{\pi \gamma}{3 \cos. (\beta + \varphi + \varphi')} R (H + R \, tg \, \varphi) \Big[(H + \\ R \, tg \, \varphi) \cot \beta \sin (\beta + \varphi) \left(3 + \frac{H + R \, tg \, \varphi}{R} \cot \beta\right) + \\ R \cos \varphi' \left(1 + \frac{R}{(H + R \, tg \, \varphi) \cot \beta + 2 R}\right) \Big] \end{aligned} \qquad (21)$$

which, when the radius of the cylinder is sufficiently small compared with its length so that terms with

$$\left(\frac{R}{H}\right)^2$$

may be neglected, reduces itself to

$$W = \pi \gamma H^2 \frac{\cot^2 \beta . \sin (\beta + \varphi)}{\cos (\beta + \varphi + \varphi')} \left[\tfrac{1}{3} H + R (tg \, \beta + tg \, \varphi)\right] \qquad (22)$$

If the cylinder is infinitely long or very thin in proportion to its length, so that

$$\frac{R}{H} = o$$

approximately, then this expression is reduced to

$$W = \tfrac{1}{3} \pi \gamma H^3 \frac{\cot^2 \beta . \sin (\beta + \varphi)}{\cos (\beta + \varphi + \varphi')} \qquad (23)$$

Differentiating equation (22) and denoting by

$$\pi \gamma (x^2 - R^2)$$

the ratio of variation

$$\frac{d W}{d H} \quad . \; .$$

we have

$$C' [H + R (tg \, \beta + tg \, \varphi)]^2 - x^2 = R^2 [C' (tg \, \beta + tg \, \varphi)^2 - 1] \qquad (24)$$

where

$$C' = \frac{\cot^2 \beta . \sin (\beta + \varphi)}{\cos (\beta + \varphi + \varphi')}$$

Graphically, therefore, the pressure to be exerted on the long and thin cylindrical vessel is represented by the weight of an earth volume intercepted below the upper surface of the earth between the cylindrical surface of the vessel and the hyperboloid of revolution produced by revolving the hyperbola (24). *Fig. 4* refers to this case for values $\varphi = 30°$, $\varphi' = 25°$ and $\beta = 20°$.

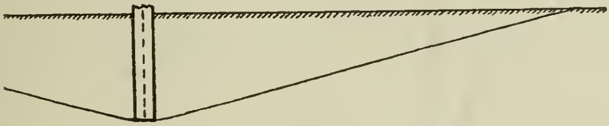

FIG. 4.

In the last of the four problems considered, the pull to be exerted on the cylinder will be, by (11),

$$F = \pi \gamma C R H^2 (1 + \frac{H}{3R} \cot \beta) \tag{25}$$

where

$$C = \frac{\cot. \beta . \sin (\beta - \varphi)}{\cos (\beta - \varphi - \varphi')}$$

Differentiating, denoting by

$$\pi \gamma (x^2 - R^2)$$

the ratio of variation

$$\frac{dF}{dH}$$

we have

$$C (H + R \operatorname{tg} \beta)^2 - x^2 \operatorname{tg} \beta = R^2 \operatorname{tg} \beta (C \operatorname{tg} \beta - 1) \tag{26}$$

Hence, the pull on the vessel is graphically represented by the weight of an earth body intercepted between the upper surface and the bottom of the vessel and between its cylindrical surface and the hyperboloid of revolution produced by rotating the hyperbola (26). *Fig. 5* refers to this case for values $\varphi = 30°$, $\varphi' = 25°$, $\beta = 40°$.

In what precedes, the angle, β, of the sliding plane or conical frustum has been considered an indeterminate quantity, as, in fact, it can take any value, provided only that it makes the pressure positive. The assumption that the actual sliding surface should correspond to a maximum pressure is totally unwarranted. That, on the contrary, it should correspond to a minimum resistance, as claimed by Moseley's principle of least resistance, is also unwarranted, at least in earth with cohesion. That the earth wedge will actually slide as supposed, may not always occur. Values of β which make the pressures negative would indicate that the suppositions do not hold good. The cohesive force in the earth must also influence the results, as when, for instance, in pile-pulling, the earth wedge may be lifted a little with the pile, thus sliding upwards.

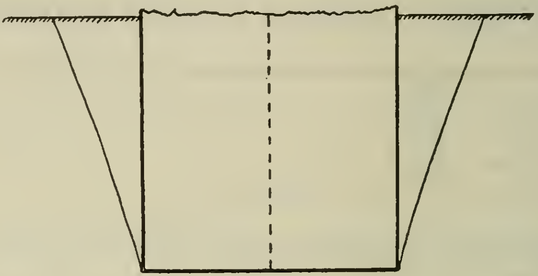

FIG. 5.

ELECTRICITY IN THE MODERN CITY.*

BY THOMAS COMMERFORD MARTIN.

A few months ago, in urging the technological needs of the Western metropolis, a Chicago orator asserted that his wonderful city was the creation of engineers. I could not but feel that he was unmindful of the work done by the farmer and the pork-packer; yet so far as the visible, material city is concerned, with its lofty buildings, ramifying railroads, beautiful parks and other accessories of civilization, his remark was broadly true.

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* Abstract of lecture delivered before the Franklin Institute.

Indeed, it would be reasonable to maintain that the modern city comes nearest to the ideal when it best expresses the aspirations and achievements of modern engineering; with the corollary that a city is not modern whose inhabitants do not enjoy all that can now be had in improved sanitation, rapid transit, intercommunication, water supply, lighting and domestic conveniences.

The dictum I have quoted is apt to set one thinking, and of late I have found myself testing the progress of electricity by the extent to which it has entered into the environment of dwellers in the city. How far has the electrical engineer contributed to the welfare of the citizens of Philadelphia, for example, or in what degree might they benefit by his work if they chose? The concrete answer to a direct question of that kind will be useful and instructive. It is likely to embrace all the modern electrical arts, for, outside of meteorological observations, electricity has thus far done little good to rural peoples—their "good time," electrically, is coming. I might almost say that it is largely due to the development of the modern city that the electrical inventions of the present century have been so successful. We do not realize as we should, that the electrical arts are all of late and recent maturity. The *word* electricity is of remote and dim origin, coined perchance by an observant artisan on the shores of the Ægean, as he strung together, in the violet twilight, a necklace of amber beads, and polishing them softly, noted their quick, responsive gleam. The *art* electricity, as the name of this Institute reminds me, dates from the authentic yesterday; its forefathers were among those of our young Republic, and it was not until the present decade that one of your own citizens and members, Prof. E. J. Houston, gave precision for the first time to its nomenclature and phraseology in the English tongue.

The truth is that the utilization of electricity had to await many other refinements in the things of this life. It is, in a sense, the most feminine of all the great natural agencies that have been employed from age to age by the human race to promote its convenience and happiness. It is the agency that most dispenses with brute force, and, whether in the telegraph, the telephone, the electric light or the electric motor, depends rather upon brain than upon brawn for its successful use. It yields us purer, sweeter subtler, gentler service than any of its predecessors in the field of illumination, heat and power have afforded us; and it cannot but be that this rarer delicacy will elevate all who enjoy it, taking us one step further from the crude, the raw and the barbaric. You know as well as I how deeply this idea has already penetrated the popular consciousness. The manner in which the leaders of public thought, or those who seek to mould public opinion, direct attention to electricity, is very striking. In reality, some of their suggestions and nostrums are as curious as those of the quacks who recommend electricity as a panacea for physical ills. Edward Bellamy, in "Looking Backward," gives a prominent role to electricity as a prime agent in his Gradgrind, workaday millennium. August Bebel, the celebrated German socialist, in his book on "Woman," asserts mysteriously that electric power is to take the first place in wiping out the "bourgeois world," clearing the world for the socialized community, and "contributing enormously to the amelioration of human conditions of existence." I, for one, shall be contented with something far short of either dream—happy, if, thanks to electricity, I may loaf and invite my soul once in a while, conscious that I am lazy for the mere selfish pleasure of it; and grateful, if, on the other hand, the extended use of electric power in mending human conditions of existence will come to the rescue of my wife by simply settling the servant girl question, and by abolishing stairs.

Now that is what "Electricity in the Modern City" means, when the argument is summed up; and all that we need is more of it for everybody. If we have electrical communication of intelligence, we save time. If we have electric light, we gain in health. If we have electric travel, we secure more leisure. If we have electric power, housework and any other work can be done with less effort. These, then, are things to strive for, and to use our influence in promoting. Such aims and ends are the very ones for which this noble Institute was founded; this promise is the breath of hope through all its departments and all its plans for the future. The electrician can only be useful and successful in so far as he plants himself squarely in front of the social, economic and mechanical problems of the age, and brings his new art to bear on their solution.

One or two branches of my subject have become hackneyed from every-day familiarity through many years, and yet hackneyed only in a very limited sense. We all talk about the telegraph as though it were something of such terrific importance to us that nothing short of a big Government monopoly would give us all of it that we want. The bitter complaint of a friend of mine up-town in New York, that the nearest telegraph office to his house was three blocks away, set me investigating. On inquiry, I found that the local Western Union offices in New York city exchanged among themselves the wonderful total of 700,000 messages last year, or, even upon the basis of Mr. Porter's belittling census, barely one per year for every two inhabitants. The average for the whole United States is about one message per year per head. The local tariff of twenty cents per message can hardly be regarded as severe, since it about equals the car-fares that would be paid if one carried one's own message and returned; so that as regards the inner social life of a modern city the telegraph is not the vital necessity it has become between points widely apart. The statistics from Europe, where social telegrams, among denser populations, are more numerous, bear out this idea, and I do not know that we shall see ever much of a change. Mr. Wanamaker has shrewdly suggested making post-offices a receiving place for telegrams, but I doubt seriously whether that would markedly stimulate local telegraph business. In fact, telegraphing is not a universal boon to individual citizens. The telegraph ratios, under our free institutions, with more or less of private competition, vary very slightly from those of monarchical Europe with Government systems, so that we may infer from them that there are strict limitations on the social use of the telegraph wires. Happy the nation, it is said, that is not making history; happy, say I, the countryman who is under no necessity to send or receive a telegram.

Moreover, there are two other electrical agencies, which, by their superior utility, act as a great check upon the local telegraph service, namely, the district messenger and the telephone. Both of these forms of communication are important. I am not among those who believe the district messenger boy to have been created for the sole benefit of the alleged comic paper. The slowness of the messenger boy has become as tiresome a joke as the extortion of the plumber, or the sleepiness of the Philadelphian; and we all know how foolish and empty those witticisms are. It is very easy to find out what the average district messenger boy accomplishes with the help of the electric system that brings his services into play. In New York, the messenger business of the district telegraph companies requires the services of 1,200 boys, and the number of errands performed by those boys last year was 2,600,000, or not less than six a day every day in the year, rain or shine, well or sick, Sundays and holidays. If you think that is not good work, apply the same average to your own office boy, and see where he comes out. Please remember these figures when the little chap in uniform comes around to see you at New Year.

The telephone is preëminently an instrument for local use. Its special utility is derived from the fact that it is practically instantaneous, affording usually an immediate response to the message. Besides, it is absurdly cheap to anyone who has a real necessity for such quick intercommunication. The telephone exchange in this city, over which my friend Dr. Plush so ably presides, handles daily nearly 30,000 telephonic connections. That costs each subscriber less than five cents per talk; while each subscriber has also the opportunity of reaching out to New York, Washington, Baltimore, Boston, Pittsburgh, Buffalo, and even Chicago. Are there any in my audience who will say that their talk over the telephone each time they use it is not worth five cents? Obviously, the telegraph in the city is under serious disadvantages from competition, and I do not see how it can reduce its charges to an equality with those of the telephone, for, cheap as the telephone is, there is a possibility that, with improvements in methods, the running out of patents with royalties, and the increased use, telephonic service may gradually become cheaper. Last year, I may add, the urban population of this country sent 500,000,000 telephone messages, or ten times as many uses of the telephone as of the telegraph.

I think we must all look forward to the time in the near future, when we can have the telephone in our homes, in our hotels, and for separate office use. In my own office in New York City, our business manager has worked out and applied an ingenious telephone system, by means of which, eight different departments are connected together without the aid or intervention of a switchboard, or a "hello girl." On each desk stands a portable telephone set, and all that is needed in beginning a conversation with anybody, is to press a small plug in the proper hole in a little annunciator box. I have thus talked with three of our clerks in a single minute. Evidently here is a great gain in the dispatch of affairs in a busy office, a great saving of time, and a great reduction of running about.

As to the saving of time effected by the telephone, as well as the economy of labor, I may point out that on the basis of six messages per day to the messenger boy—the present average—Philadelphia would need 5,000 more district boys than she now boasts of, to carry one way her messages now sent by telephone. While I do not abate a whit of my advocacy and praise of the boy, I think we all prefer the telephone.

There are two incidental uses of the telegraph that closely affect city welfare, namely, the fire-alarm system and the police-patrol system. Both of these are essential elements to-day in city safety and welfare, and the former is well established. In 1890, for example, fifty miscellaneous cities in this country had no fewer than 8,400 fire-alarm boxes in use by their fire departments. It is needless to point out that this ability to give a prompt alarm does much to keep down the loss from fire, which appears to run about $2.25 per head in cities of over 100,000 inhabitants and which would be much larger if there were greater delay. Many of our buildings now have automatic fire-alarm systems, but I look forward to the time in the near future when city ordinances will compel every large building, no matter how "fire-proof," to connect itself with the nearest fire station, either directly or through the telephone exchange. As to the police patrol system, I can only say that in nearly all our large cities its application is still very defective and inadequate. There are no statistics on the subject, and much of the work has been tentative. It must be evident that a system under which every policeman is put in direct touch with his headquarters, at his own will, or by call from his chief, means an enormous increase in the efficiency of the force. In our largest cities to-day, there are about fourteen patrolmen to the square mile, giving each man about one and one-quarter miles of street to guard. With an effective communicating system, known by evildoers to be readily available by the officer, the attempts at crime and the escapes would be much less numerous. In cities of less than 100,000 inhabitants, where there are barely four patrolmen to the square mile, such a system of bringing reserves quickly to any point of need is even more greatly to be desired and recommended. These are days when shrill whistling and three taps on the sidewalk are sadly primitive means of ensuring the public peace. The burglar alarm and the police patrol are none too good as an offset to the scientific cracksman and the drunken tough.

Probably that branch of applied electricity which of late years has made the deepest impression in our cities, is electric lighting. I do not expect any one will challenge the statement when I say that the electric light has been one of the greatest boons of modern invention. I said "boons" not "booms," for as a matter of fact the progress in the use of the electric light has been amazingly slow. There has been a great development of arc lighting for the streets, and we now see very little done in the way of erecting gas or oil lamps in city thoroughfares. Investigation of a group of 278 cities, ranging in population from 10,000 to 100,000 and with an aggregate of 7,000,000 inhabitants, in 1890, showed more electric street lights in use than gas lights; and the tendency everywhere is steadily towards the complete supercession of gas. But, after all, such an employment of electricity is a very small one. There will be more arc lights in the single Manufactures and Liberal Arts Building at the World's Fair than the city of Philadelphia now pays for on all its streets. Hence, I do not think we have too many of them yet. I must confess to an humble opinion that they are an element of beauty in the city, shining as they do so whitely and insistently, like Shelley's "radiant sister of the day," and recalling, every time one looks down a long stretch of them, that striking passage in the old English poet, Marlowe:

> "For every street like to a firmament
> Glistened with brea hing stars."

Perchance some of you may not find in them the appeal to the imagination that I do, but you will agree with me that their utilitarian side is also a strong one. That is the view taken of them by most civic authorities, who hold the ordinary arc light to be as good as a policeman. Sometimes it is equal to two.

It has been estimated that, of the total candle-power which can and which should replace gas-lighting, about five per cent. will be furnished by arc lights. The inference therefore is, that the incandescent light has a larger part to play than the arc in city life. This is exactly the case; and it is only when we come to examine the figures that we realize how little has been done towards the universal adoption of electricity for our homes and offices. The dynamo capacity in the United States to-day for supplying current to incandescent lamps is about 5,000,000 lights, and the number of lights wired up is about 7,000,000 or 8,000,000. The production of incandescent lamps runs about 25,000 to 30,000 a working-day all the year round, making a rough total of 8,000,000 to 9,000,000 lamps manufactured for consumption. As the average life of a lamp is about 800 hours, and the average use is about two hours daily, we will see that lamp production and lamp consumption pretty fairly balance. But the total result is, to say the least, disappointing. It is a reasonable assumption, supported by various figures, that there are two gas burners per head of population in our cities; I believe gas consumption is often broadly estimated at about one active burner per head. Hence, it would follow that New York and Philadelphia to-day, if gas were abandoned or used as power at the point of production and electricity were universally adopted in its stead, would at once need all the dynamos and lamps now made and used for supplying the whole of the United States. And yet the combined population of the two cities barely reaches 3,000,000, or less than one-twentieth of the population of the country. The same basis of calculation would thus give us, for the United States, a dynamo lighting capacity of 100,000,000 incandescent lights and a lamp production of 600,000 lamps a day. If we cut that in two, so as to consider merely city population, there still remains an enormous field that has yet to be occupied.

Now, I do not think I overstate the case when I say that everybody in American cities would like to use the incandescent light, if possible. What then, have been the reasons that have so far stood in the way of gratifying their desires? Three reasons, I should answer. First, the high price of current; next, the scarcity of the supply; and third, the cost of the lamps. The first two reasons merge into each other. You have, in Philadelphia, one of the largest and best managed incandescent lighting stations in the world, and I shall show you a later one, a rival lately equipped and started in Boston. But both of these stations are in reality still producing on a retail scale, in view of the area to be supplied. I have shown that Philadelphia would need about 2,000,000 incandescent lights wired up. I doubt if the station I speak of can supply more than 100,000. Hence it follows that with gas to be consumed by 2,000,000 burners, and electricity by something short of 200,000, the odds as to price of light are very much against electricity. The marvel is, that already, with one industry more than half a century old and the other barely ten years old, a parity of price has been established. A curious feature of the situation is that the coming of electricity has largely increased gas consumption in many instances. The old unit of ten candle-power gas no longer prevails, but gas men and electricians all talk now of sixteen candle-power units. Moreover, I have often noted, of late years, that in stores where gas has been adhered to, a great many more burners have been added, in order to gratify the eyes that have been attuned to a better means of illumination.

Can I promise the coming of a time when we who live in the cities can all have the electric light cheaply—in other words, at will and at no greater cost than gas anywhere within the limits of a modern city? Yes. With our present conditions, the time will come slowly, but I sometimes think the discontent which we feel in view of the slowness of its approach will hasten the perfection of new ideas and new apparatus. Many of you have heard my friend, Mr. Nikola Tesla, tell how by means of currents of high potential and high frequency, he could distribute current over very small wires and with it use lamps that have no filaments at all in them; so that he has at once cheap distribution and a lamp that never wears out. I know that when Mr. Tesla "arrives," as our French cousins say, gas will not be "in it," as our Bowery cousins say; but, meantime, we are confronted, not with a mere vision, but with the fact that gas is sold at $1.25 and $1.50 per thousand. Well, we shall steadily proceed to equalize things by increasing the quantity of current we manufacture. According to the Courts of Pennsylvania, we do manufacture current. We are pulling down our old stations and building greater; we are simplifying the machinery and installing larger units for the generation of current. We are also steadily reducing the price of lamps. We are trying many new types. Besides that, we are now witnessing the production of ingenious devices with the laudable aim of cutting down at will the consumption of current in any lamp, so that the incandescent light can be burned at different degrees of brilliancy. These are useful, operative mechanisms, and promise to accomplish much in popularizing and cheapening the illuminant which is still new.

Beyond all that, we have a great variety of apparatus that is increasing the demand for current, and thus cheapening the supply. I refer chiefly to electric motors and to electric heaters. The introduction of these appliances means much to a central station, and therefore much to the public. The chief hours of lighting are usually limited between 5 p.m. and 12 midnight, with a maximum of only half that time. Gas works have been able to depend on the daytime use of gas for gas engines and for cooking and warming; but until lately central stations have had no corresponding day load, and they have been at a corresponding disadvantage as to opportunities of income and profit. But now the use of electric motors and electric heaters is changing all that. It is no uncommon thing for a central station to-day to supply current for hundreds of motors employed in an endless variety of work. These motors are jacks-of-all-trades and popular in each of those trades. They are cheap, easy to run, and economical of space. They generate no heat or smell, and they are obtainable in any size from fractions of a horse-power up to motors driving whole factories. The rates for current range from four to ten cents per horse-power hour. To-day, instead of having boilers and steam engines scattered all over a city in small, expensive units, the generating plant is located in a region where smoke and steam cease to annoy the neighborhood, and an electric motor becomes the medium of distribution. Going along our streets on torrid summer days and getting a whiff of hot air from the nether regions where a steam plant is in operation under the sidewalk, or in some dim, stuffy basement, I wonder to myself that this electric innovation does not make quicker headway. But the change is going on, and such cities as Philadelphia, New York and Boston now have literally thousands of horse-power in electric motors. Moreover, steam or gas is not the only agency utilized to drive the generators of current. Very soon Buffalo will have 100,000 horse-power on tap from Niagara, twenty miles further down stream; and thus we shall see the contradiction on a grand scale of the old adage that you cannot grind with water that has run by.

The electrician is not so far advanced with heaters as with motors, but he has already reached firm ground. The heater to-day is at the same point of perfection as the motor had touched ten years ago. As a device it is fully operative, but it is still very inefficient. Its use depends, therefore, upon its improvement, upon a cheap supply of current, and upon the new features of advantage and comfort it may present. In some cities it is already a fairly familiar object In Ottawa, Canada, it is in use in barbers' saloons, drug stores, livery stables and bakers' ovens, and is now being applied to the warming of houses and offices, current for all the devices being obtained by the utilization of the Chaudière Falls, whose name has thus contained a happy prophecy of their modern service.

Aside from the cost, it is obvious that there will be no carting in of coal, no disposal of ashes, no smoke, no soot, no dust to settle on furniture and tapestries, no sacrifice of the whole cellar to the heating system, no martyrdom in the kitchen during the summer, no fiery blasts from the register, no wintry breezes in the upper rooms, no bombardments of Alexandria in the steam pipes. On the contrary, there is the immediate noiseless heating of any room or of the whole house at any minute, the paradoxical keeping cool on a sultry March day, and warm on a bleak July day; the possibility of making coffee or grog in five minutes; the ability of keeping a foot-warmer warm all day and a bed-warmer warm all night; the chance of using one's cellar as a billiard room instead of a depot for Reading coal, against the next rise in price.

Back of all this is the great fact that wherever soft coal is used, electric heaters will help wipe out the smoke nuisance, with its grim attendant, fog. Fog and soot and smoke mean disease, and as we have, each one of us, to repel about a dozen infectious diseases every week of our lives, it is well to clear the atmosphere of everything that may give wings to the germs. The application of a smoke consumer to a large central station is easy, while, as Chicago shows, it is still practically impossible to consume the smoke from thousands of individual coal fires. What a smoke fog means in London we may infer from the mortality statistics of 1879–80 when the deaths from bronchitis increased 331 per cent. above the average, and those from whooping cough 231 per cent.; or from the statistics of 1890 to 1892, when the blight of the London fog extended to the vegetation at Maidstone, the center of the hop region, thirty miles distant. Need we wonder that a recent brochure depicting the doom of London, describes the asphyxiation by fog of all her 4,000,000 inhabitants, save one man, who escaped as by a miracle, to tell the sad story.

Before I leave this branch of my subject, I would like to point out that electric heat, light and power will do even more to give us a cleanly, beautiful city if we burn up the refuse and rubbish in what are known as "destructors" instead of dumping them where they do the least good. In New York, we cart the loose refuse through long stretches of breezy city street, then bank it up carelessly on open barges and tow it out to sea—when not too rough. The Atlantic rejects it, as would any self-respecting ocean, and so it floats about until the vile jetsam spoils the whole range of bathing beach from Far Rockaway to Normandie-by-the-Sea. It may be the evidence of a high civilization thus to greet the enthusiastic newcomers from Europe with the contents of our dust bin, but I think the effect would be as fine if we burned the rubbish in a destructor on Liberty Island. It would then speak in parables through the welcoming torch of white electric flame that tells of a land where old things become new and where that which was outcast is transmuted into living elements of beauty and power.

I have now dealt with electricity in the modern city as applied to the communication of intelligence, the safety of buildings and streets, and the means of light, power and warmth. I come now to the vital and important questions of travel and transportation.

Five years ago the electric street railway was practically an unknown thing in America. The first statistics of the industry were compiled by myself in 1887, and showed a baker's dozen of short, experimental roads, with crude apparatus, and handicapped by a grave suspicion on the part of the public that an electric motor was about as likely a means of rapid transportation as a balloon. Four years ago I sat in a national street railway convention at our national seat of government, and heard an indignant delegate complain that he was there for the purpose of learning how to shoe horses and dispose of manure—certainly not to listen to all this newfangled stuff about electricity.

Yet, as my presence here to-night and my subject would indicate, the electric railway, in a very special sense of the slang phrase, "got there." The suddenness and brilliancy of its development have been equalled only by the abuse and the calumny that have marked its advance. Like every new thing, it has had its shortcomings; like every great invention, it has still to pass through many stages of improvement; like many an innovation, it offends some tender sensibility or deeply-rooted prejudice; and the old battle that has been fought so often has to be fought again. Considering how universal among progressive peoples is the desire for good roads and swift travel, one is rather at a loss to understand why the electric railway is opposed; but I have not the slightest doubt that when an etheric railway is advocated in the year 1993, some slow ultra-conservative will rise in his wrath and say that electricity is good enough for him, as it was for his father before him. There is a curious revelation of prejudice in the remark of our own General Webb, in 1835, who, after a railroad journey with ladies from Boston to Providence, exclaimed in disgust: "To restore herself to her caste, let a lady move in select company at five miles an hour, and take her meals in comfort at a decent inn." I fancy I see the ladies of Philadelphia, *en route*, for New York, restoring themselves to their caste on this basis. And yet this utterance, or the horror-stricken protest of Philadelphia against the introduction of gas, I could match with many a passage from the American newspapers of to-day about the electric railway, with its "deadly trolley" and its "death-dealing wire."

[*To be concluded.*]

ENGINEERING PRACTICE AND EDUCATION.

BY GAETANO LANZA, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from p. 139.*]

Let us now consider briefly some of the functions of the electrical engineer, and the character of the work commonly known as electrical engineering.

The present extensive applications of electricity are of comparatively recent growth, and it is only of late years that such applications as are intimately connected with the work of the engineer have been developed to any great extent.

The realization of this class of applications is due especially to the great development of the methods for the electric transmission of power, and to the extension of electric lighting; although various other applications, such as electric welding, the telephone, the telegraph, railway signaling, etc., are also closely connected with engineering work.

Heretofore the civil engineer, or the mechanical engineer, so called, has not considered electricity as an essential part of his work, but as something which he need only cultivate if the special work in which he was engaged led him in that direction. But the signs of the times seem to be that before long the engineer will be so likely to meet with the use of electricity in one form or another, whatever be the special line to which he devotes himself, that it will become an absolute necessity for him to have a certain amount of training in that subjcect, as well as in such general subjects as mechanism, strength of materials, steam and hydraulics.

However, the term electrical engineer to-day is used to denote a mechanical engineer, having special training in the theory of electricity and its applications, and whose special work is in the line of the practical applications of electricity. The greater part of his work is the usual work of the engineer, the remainder having to do directly with electrical appliances. It must be borne in mind that electricity, when used on a large scale, must be generated by some external source of power, as by a water wheel, or more commonly by a steam engine; that dynamos and electric motors cannot be operated without a power plant; also that the object of electric motors is to drive machinery of some sort.

Suppose, for instance, that the electrical engineer is called on to establish an electric light station. The engineering problems arising are, in a certain sense, similar to those which would arise in building and equipping a large factory, his special machines in this case being the dynamos and connected machinery and apparatus, the manufactured product being the light. He must determine the number, size, kind, etc., of his dynamos, switchboards, etc., having regard to the requirements of the service, to the amount of light he is liable to be called upon to supply, to the district in which the lights are situated, and making allowances for a reasonable growth. All this deals directly with the electrical side of the work. He must then proceed to locate the machines, having due regard to the work to be performed, and also to the arrangements of shafting, belting, pulleys, etc., by which they are to be connected with the source of power. These last are purely engineering questions.

Then he must locate and arrange his power plant; boilers, engines, etc., determining what kinds, what sizes, and how many he will use.

Then comes the arrangement of the whole system of power transmission from the engine or engines to the dynamos. Then comes the erection of buildings to contain the machinery, in which due consideration must be given to the questions of strength, of stability, of lighting, of heating and of ventilation; also to securing proper foundations for the buildings, and for engines and boilers, and other heavy machinery that cannot be placed on the floor of the building; also to the design and erection of a suitable chimney. Then of course questions of water supply and of drainage arise.

All these are engineering questions, and he will meet a number of others when he proceeds to carry the wires through the streets to the points where the light is to be furnished. If they are to be strung overhead on poles, the strength of the cables, the strength of the posts, etc., are important things to be considered. If they are to go underground, other engineering questions arise, such as the proper protection of the cables from moisture, etc., the means of running out branches from the mains, and other related problems.

Now, in the power station of an electric railroad, we have just such problems as the above, besides questions that arise in connection with the permanent way and the rolling stock; also, if the company intends to make its own machinery, in whole or in part, suitable shops must be built and equipped, such as boiler shops, etc.

I shall not attempt to give a description of such a power station, but will pass on to give as an illustration a summary statement of the different kinds of machinery manufactured by the General Electric Company.

Practically, these works might be said to manufacture machinery for electric power transmission and for electric lighting, but on close examination we find that these two divisions include a very large variety of machinery and apparatus. Thus, the first involves the making of dynamos, railway motors, tramway motors, mining locomotives, electric locomotives, snow-sweepers, trolleys, motors for stamp mills, mine hoists, elevators, air compressors, rock drills, mine pumps, blowers, cranes, rock-breakers, coal-cutters, coal-drills, etc., and, in addition, all the accessory electrical apparatus, including switchboards, voltmeters, ammeters, rheostats, resistance coils, etc.

Furthermore, the various systems of electric lighting—arc, direct incandescent and alternating incandescent lighting, involve the making of dynamos of the kinds suitable for each, switchboards, regulators, lamps, lamp fixtures and a great variety of apparatus necessary in connection therewith.

Now, from what has been said, it is plain, I think, that much engineering work must be carried on in connection with the use of this machinery, but I will pass to a consideration of the factory itself, where these things are made, and, without attempting to give any adequate description of it, I will call attention to a few of its engineering features.

It comprises a large workshop for manufacturing machinery varying in size from a huge and heavy dynamo and motor, to the minute pieces that form the parts of a voltmeter or of an ammeter. Hence we have practically the same engineering features and problems that would be found in every large machine shop fitted with such a variety of tools as to be able to perform both heavy work and very light work, with the difference that in this case we find, in addition, special arrangements for doing the work that is peculiarly electrical, as the testing of the different parts of the machines, and of the entire machines by means of delicate electrical measuring instruments.

Now I have often enough detailed in one connection or another the engineering features that enter into the design and erection of any such plant, and I shall only say that there is opportunity here, which is taken advantage of, to use electric means of power transmission, and hence to not only introduce electric cranes, but also to drive a number of the individual machines by electric motors. This is a feature which is not peculiar to these works, for electric cranes are in general use in foundries, machine shops, etc., and the electric motor for the transmission of power, is coming into general use.

These works are building some large electric locomotives, making not merely the motors, but every part of the machines; while, by way of contrast, their lamp factory affords an instructive example of a well-organized shop for turning out small and delicate work. Finally, an important part of this great establishment is the very large draughting department, with a carefully arranged system by which drawings and blue-prints are kept so as to be readily accessible for reference.

Without dwelling longer on this and similar illustrations, I will say a few words about the telephone, a subject which most of my hearers will doubtless think is very remote from engineering; nevertheless we will find in connection with it a large amount of engineering work.

The wires have to be carried from the central exchange station to the points where the subscribers are situated; and they must be placed either overhead, underground, or sometimes under water. When they run overhead there are to be considered the strength of the poles, the manner of setting them firmly in the ground to enable them to resist any load they are liable to have brought upon them, and of strengthening them when necessary by guy ropes; the strength of the cable and the tension upon it, and the strength of the cross-pieces which carry the cables.

Now, when the installation is to be underground, the cables radiating from the exchange must be suitably arranged, so that any one of them can be taken out independently of any others. This arrangement involves very careful engineering. Then comes the consideration of how the cables shall be protected underground, how they should be arranged so that each one may be drawn out at any manhole in the street just as at the exchange, how to avoid gas pipes, water pipes, etc.

If the cable goes under water it must be covered like a submarine cable, and then sunk to the bottom as is done with telegraph cables. This becomes a little difficult sometimes when the tide and current interfere with laying it in the desired position.

The exchange building should be designed specially for its intended purpose, and should be made strong enough to stand the heaviest loads to which it can ever be subjected. One of the most complicated problems to solve is how to introduce cables from the street and carry them to some central point in the building without interference.

These illustrations will suffice to show that one who is not an engineer cannot be an electrical engineer, and that the greater portion of the work of the electrical engineer is such as to require a knowledge of other branches of engineering.

As our next illustration we will take refrigerating machines, their manufacture and operation in making artificial ice, but more especially in cooling rooms, the latter finding its chief application in cold storage; an industry of very recent growth, but one which is of the greatest importance both on sea and on land, and which is rapidly growing.

For a number of years ice has been made in warm countries by means of absorption machines. In these, a concentrated solution of ammonia contained in a vessel, called the generator, is heated, and the ammonia, thus distilled off, passes through a condenser, where its heat is abstracted from it, but where it remains under a considerable pressure. It is then allowed to expand into a coil arranged in a tank of brine, which is cooled by it to a temperature below the freezing point of water. The ammonia absorbs the heat of the brine, and is then itself absorbed by a weak solution of ammonia contained in a vessel called an absorber, with which the coil communicates. The solution of ammonia in the absorber, when it has become more concentrated, is pumped into the generator, and the process goes on continuously. Then the cans of water are placed in the chilled brine, by contact with which their contents are frozen; or, if the object is refrigeration and not ice-making, the chilled brine is pumped through a coil which passes through the room to be cooled.

Such a method as this is inefficient, and is not suitable for work on a large scale. Hence, until a better one was discovered and its success fully demonstrated in practice, no great development was possible for refrigerating machines.

The modern refrigerating machine is a compression machine, which is arranged as follows: A steam engine drives a compressor, which receives the ammonia in the form of vapor from the other end of the system and compresses it, heating it, of course, at the same time. The compressed ammonia passes into the condenser, consisting of a coil of pipe, on the outside of which water trickles, carrying off the heat from the ammonia and liquefying it. From here the liquid ammonia passes into a separator where the ammonia settles to the bottom, and the oil taken up in its passage through the system rises to the surface, and is drawn off whenever it is deemed desirable. From here the liquid ammonia passes through a valve and expands into a coil of pipe, which passes through the brine in the brine tank, and here the brine is cooled, its heat being expended in the re-evaporation of the ammonia, which is then led back to the compressor while the brine is pumped through the coils in the rooms to be cooled, or placed in contact with the cans containing the water to be frozen.

Such machines require for their development and successful construction, a careful application of the laws of thermodynamics. For ice-making, they have become absolutely necessary in warm climates, and are used to a considerable extent also in cold ones. For cold storage they are needed everywhere. Cold storage necessarily demands a structure, in which, even in the hottest weather, a series of rooms are kept so cool that meat, eggs,vegetables, etc., stored therein will be preserved from decay. By the use of cold storage on shipboard, meat can be sent across the ocean, and the benefits conferred by it on land are so evident as hardly to need enumeration. Fruits, for example, gathered at the proper season, may thus be kept in good condition for a long time, and brought to market when such products are entirely out of season; and meats, eggs, etc., may be kept fresh for a long time.

The building of the Quincy Market cold-storage plant in Boston is on piles. The outer walls are double, having between them an air-space, which is packed with shavings. The inner walls are packed in the same way. The building is located near the harbor, so that cold water from the dock can be pumped up for use in the condensers. The building had to be adapted to: (1) the storage; (2) the plant; (3) the conveyance of the brine. In arranging the building for the storage, it was necessary to provide a suitable number of rooms to accommodate the different classes of food products, and these rooms required to be insulated from their surroundings, so that the temperature of each one could be kept at the desired point, independently of the others.

There are two engines, each running a compressor. The water for cooling the ammonia in the condenser is pumped up from the dock, and, after performing this duty, is returned to the dock by gravity.

The brine tank contains 4,500 gallons, and has a capacity of 250 tons, only 100 of which are at present utilized; but the intention is to put in a new compound engine of larger capacity (about 150 horse-power, I think) as soon as business warrants it. The usual method of refrigeration is by means of a coil of brine pipe placed around the inside of the room. At the Quincy Market, however, an indirect system is used for some of the rooms, the air being drawn by a fan over a coil of cooling pipes erected at one place in the room.

Electric lighting is used throughout the building. A machine shop and piper's shop are being added. The tank room is, of course, well protected from heat by thoroughly packing the walls, roof and floors.

If you should walk through the building and look into the different rooms, you would find them filled with all sorts of perishable materials in a good state of preservation. You would find pears, peaches and all sorts of fruit and vegetables stored here to be kept for a later market. Elsewhere you would find poultry and other meats in a frozen condition. You would observe also that the temperature of each room is regulated to a nicety, according to the requirements of the products stored, or intended to be stored, in it.

Doubtless. the largest establishment in this country for the manufacture of refrigerating machinery is that of the De la Vergne Company, of New York. The special features of the refrigerating machine which this firm manufactures are that oil is introduced with the ammonia into the compressor cylinder, partly for lubrication, partly for the sake of preventing leakage, partly for decreasing the clearance space, and partly to absorb a portion of the heat developed during the compression. Besides these there are also certain special features of construction, some of which are intended to decrease the number of joints that have to be made up; and thus to decrease the leakage.

The works are very extensive, including three large main buildings, and a fourth building, which contains a blacksmith shop and a pipe shop.

These works are quite modern and have, of course, the general features of a modern plant for the manufacture of machinery. An erecting shop has lately been added, and here every attention has been paid to securing light and to convenience of handling materials, and every separate machine is run by its own special electric motor. This avoids the use of shafting, with its pulleys and belts.

Turning our attention next to those industries in which chemistry plays the leading part, we enter the field of the chemical engineer. We will take up only two of his specialties, viz.: the refining of sugar, and the manufacture of paper.

Sugar Refining.—I will begin by outlining briefly the process that must be followed, without attempting much detail; and in doing so, I will have in mind the routine of operations practiced in the Standard Sugar Refinery, at South Boston.

The raw sugar is received at the refinery in bags or sacks, from which it is emptied into the melting kettles. These are large, covered, cylindrical chambers built of brick and cement, and provided with a number of coils of perforated steam-pipes. Steam is now let on. This melts, and of course, dilutes the sugar. The resulting liquid, containing about fifty per cent. of sugar, is now pumped to the blow-ups, which are large tanks, situated higher up in the building. Into these tanks, air is blown for the purpose of keeping the liquid in a state of agitation and consequently thoroughly mixed. This counteracts the tendency of the liquid to local solidification, and at the same time reduces its temperature. A little lime is here introduced to neutralize the acidity, if there be any.

From the blow-ups, the liquid flows by gravity to the filter-pans. These are flat, shallow pans with series of holes in the bottom, and below each hole is a nipple to which is attached a bag filter. This consists of a large bag of coarse material, confined within a smaller bag to keep the large one from being distended, and failing to perform its functions. The liquid is now filtered through these bags, and the syrup passing through them is then ready to be taken to the charcoal filters.

When the bags have become so choked up with dirt as not to filter well, they are detached from the filter-pans, and the adhering material is emptied out, and taken to a filter-press. The syrup here squeezed out is taken to the melting kettles, while the residue, which is only dirt, is thrown away. The bags are then washed by passing them through running water and wrung out between rollers. The water in which the bags are washed is then sent back to the melting-kettle.

The bags are now in condition to be used again by placing the large bag inside of the small one as before. This was done with more or less difficulty by hand, until a simple machine was devised, in which automatic fingers, attached to a piston moving in an upright tube, drew the bag into the tube with the aid of a partial vacuum. The large bag is then dropped into the sheath or outer bag, the rapidity of the drop being regulated by the amount of air admitted behind the piston.

The syrup that has passed through the bags is transferred by a pump to the bone-charcoal filters. These are 20 feet deep and 12 feet in diameter. The syrup is thus decolorized, and it then goes to the vacuum pans, where the water is boiled off, and the sugar is formed. The sugar is then dropped into a conveyor, where it is made to travel along by a screw and delivered to the centrifugal machines. The water is here driven out, and the sugar is left white, and very nearly dry.

Next it is granulated. For this purpose it is introduced into the upper end of a long cylinder inclined a little to the horizontal, and the rotation of this cylinder alternately raises it and lets it fall, at the same time feeding it slowly forward to the lower end, while a series of hammers constantly jar the cylinder so that the sugar shall not stick to the sides. In this way the sugar is dried. On leaving this cylinder it is carried on a belt-carrier to the bin where it is stored. As with grain in a grain elevator, no attempt is made to keep separate the sugars made from the different lots of raw sugar.

Such, in brief, is the process through which the sugar is carried, but the bone-black must undergo a process also. When the syrup has filtered through the bone-black for a certain length of time, the latter is found to be dirty, and has to be cleaned. For this purpose the filters are opened near the bottom, and the bone-black is drawn out with a rake, and conducted into vertical retorts where it is heated to redness, and the dirt is thus burned off. The bone-black is then allowed to cool to a certain extent before the retorts are opened, and after it has cooled down further it is returned to the filters. The final cooling is accomplished by running the bone-black into a kettle provided with pipes through which cold water circulates. Under the retort is a fire which heats the bone-black to a temperature of about 700°, and it is left at this temperature for several hours. Now, as it cannot be exposed to the air at once, it is passed into sheet iron flues, and allowed to stay there until it cools to a temperature of 400°. From here it is transferred to a hopper, and this transference must be done at a regular rate and in measured quantities. This is accomplished by some very ingenious special machinery. From the hopper the bone-black is dropped upon a belt-carrier, which takes it to the kettle already referred to. From this it is taken by another belt-carrier, provided with little buckets, and carried to the room where the tops of the filters are situated, and, finally, a horizontal belt-carrier delivers it to the filters.

The above is a very brief description of the various processes that have to be carried out, and a successful performance of the work demands the greatest care and nicety of operation at all points, especially in properly sorting the different qualities of the syrups that come from the bone-filters, and in operating the vacuum pans.

Of course, the superintendent must look carefully after these matters, and chemical analyses have to be constantly made, since the least carelessness in carrying out the process may result in very serious loss to the company. Nevertheless, the process and the greater part of the chemical work become in time largely a matter of routine.

When, however, we undertake to carry out any such complicated series of processes we have to use a large amount of machinery, and extensive buildings of sufficient strength and stability have to be built.

It is frequently necessary to build wharves or quays to receive the vessels that bring the raw sugar; and to erect buildings which must provide space and facilities for storing the raw and refined sugar, and hence must sustain heavy loads. Then the portions of the building where the various parts of the process are to be carried on must be so designed as to be most conducive to economical handling. Then there is considerable opportuniy for devising special machinery and special arrangements to accomplish special objects. Thus, the syrups are usually transported from one place to another by pumping, and part of this pumping is done before it has been passed through the bag filters. All this means that we must have pumps that can raise a thick liquid, and which will not become clogged with dirt that comes from the melting kettle. Then, for transporting the sugar from place to place, and also for transporting the bone-black, belt-carriers are used, *i. e.*, endless rubber belts. In the refinery which is now being built at Greenpoint, L. I., which is the largest single refinery belonging to the Trust, and in which the greatest care is being taken to introduce the most modern and approved methods and machinery, the coal is received at a long distance from the boilers and is carried to them on belt-carriers.

Another labor-saving device is the mechanism already referred to, for sheathing the filter bags. Another is the machinery for delivering the bone-charcoal at a known uniform rate, from the sheet-iron flues to the hopper. Then there is machinery for packing, and for lifting barrels, etc. The special sugar machinery likewise (such as centrifugal machines, vacuum pans, etc.,) must be very carefully made and requires nice engineering skill in its design and construction. Besides this, a large amount of very nice engineering work must be done in connection with the evaporation in the vacuum pans, which are sometimes run with triple effect, the three evaporations being carried on successively, the steam for one being furnished by the evaporation in the next preceding one. Then of course there are the boilers, the engine or engines, the chimneys, etc. Evidently, therefore, a very great amount of engineering work must be done in order to make the plant a success.

As another illustration let us take the manufacture of paper from wood pulp, for which purpose I will give a brief description of the processes carried on at the works of the Russell Paper Company at Lawrence, Mass. The kinds of wood used are poplar and spruce. The wood is cut into chips, and these are mixed with a liquor which attacks all the ingredients of the wood except the cellulose. This liquor is put, with the chips, into a boiler or digester, into into which steam is introduced and in which the mixture is cooked for a suitable length of time. The mixture is then drawn off and washed, and the water and impurities are thrown away, and pure cellulose is left. This, mixed with water, constitutes the pulp. To make a satisfactory product, two different kinds of pulp, sulphite pulp and soda pulp are used, which are mixed in proper proportions, viz.: the sulphite pulp alone would make too harsh a paper, while soda pulp alone would make too weak a paper. The first is used to give strength to the product, and the second softness and delicacy. The sulphite pulp is made by treating the chips with an aqueous solution of sulphite of lime, the chips, liquor and steam being mixed in a spherical boiler which is kept rotating during the cooking. The soda pulp, on the other hand, is made by boiling the chips in a solution of hydrate of soda, and, instead of using a rotating boiler, the chips and the liquor are placed in a vertical cylindrical vessel called a digester. This vessel is provided with a perforated plate near the bottom, and on this plate are placed the chips. The steam is then introduced below the plate, and the liquor is caused to circulate through the chips, during the cooking operation.

In both cases, after the cooking operations are completed the pulp is pumped up to a beating machine, where it is thoroughly mixed, and the fibres are drawn out by causing them to pass between revolving beaters. Here it is also more thoroughly washed than it was after leaving the boilers or digesters.

In the case of the soda pulp it is sometimes bleached in the troughs in which the washing and heating is done.

After the pulp leaves these troughs it is made to pass through a series of very fine screens of metal plates having a series of thin slats. Thence it goes to the wet machine, which is a trough through which a continuous flannel roll is made to pass. The pulp adheres to the flannel and the water drops off. Then the flannel, with its layer of pulp, is squeezed between several sets of rollers from which the pulp layer emerges as a kind of thick paper, but destitute of consistency. Then, if it has not been previously bleached, it is conveyed on trucks to the bleaching pots. In these it is placed, together with the bleaching liquid, and the whole is stirred by agitators. From here, when the bleaching is finished, the pulp is conducted to a room with a perforated floor, where it is washed by a stream of water from a hose, leaving the bleached pulp on top of the false floor.

Next follows the mixing operation. In the trough of the mixing machine are placed the sulphite and soda pulp in the desired proportions, together with any other ingredients that may be desired, such as clay to make the paper take ink, sizing, resin soap, etc. By suitable machinery the materials are caused to travel round and round in this tank until they are thoroughly mixed. For the finer papers a Jordan engine is used instead.

After this the pulp is ready for the paper machine proper, which may be a Fourdrinier or a cylinder machine. In either case, the pulp is caused to adhere to a layer of cotton or wool, which forms, as it were, an endless belt, the water dropping off, and the pulp being carried along on this cloth, gradually passes between pairs of rolls, the first pair usually making the water mark. The pulp then reaches the calender rolls, inside of which steam circulates. Here the pulp is dried, and, as it were, ironed, and receives a gloss. It is then rolled and subsequently cut into sheets of any desired size.

The foregoing is a very brief description of the principal steps only. The following important details have still to be mentioned:

(1) When the wood is received at the mill, the bark and any other roughness are removed by a special machine, made somewhat on the principle of a milling machine. Any large knots are then drilled out, a machine being also provided for this purpose. The log is then placed in a machine containing a set of revolving knives which chips off the wood obliquely to the grain. From this machine the chips are carried by belt-carriers to the upper part of the building, where they are led to hoppers over the boilers or digesters respectively.

(2) The sulphite of lime solution is made as follows. On an upper floor are three closed tanks, arranged on three different levels and so connected that a liquid in the upper one, when it reaches a given level, will overflow into the second one, and in like manner from the second into the third. When it reaches a given level in the lowest tank it overflows into an open tank placed at a still lower level, and directly over the boilers. Above the system of three closed tanks is another open tank containing lime water, which flows continuously from this tank downwards through the entire system. In the basement is a furnace for burning sulphur, and thus forming sulphur dioxide, and the passage through which this gas escapes from the furnace leads into the lowest of the system of three tanks, then into the next and then into the upper one, from which it is pumped out by a vacuum pump, which draws the sulphur dioxide and the accompanying nitrogen through the solution in the three closed tanks. The sulphite of lime thus formed overflows into the lower open tank, from which it is delivered by means of a hose to the boilers.

(3) The hydrate of soda is made by boiling soda ash and lime water by means of a current of steam passing through a coil of perforated pipes within the boiler. The hydrate of soda is drawn off, and the carbonate of lime is thrown away.

(4) The material washed out from the pulp in the soda process is, of course, very dilute, but it is nevertheless, desirable to reclaim and to re-employ the soda. For this purpose the liquid is reduced in a Yaryan evaporator to the consistency of molasses, after which it is placed in a revolving drum, open at both ends, one end communicating with a furnace, and the other with the chimney. The inside of this revolving drum is conical. The material is thus burned, and comes out as a black ash, consisting of soda ash, carbon ash and a little sand. This black ash is leached with water, which dissolves out the soda ash, leaving behind the other ingredients, and we thus have again a solution of soda ash from which to make the liquor.

Here again we have buildings, tanks, furnaces and other constructions to erect, and a very large amount of machinery to operate and keep in repair, even if we do not have to design and build it.

I have cited, in these three lectures, a number of examples of industries where the work of the engineer is required, and, although these are only a few examples selected from an almost countless number, they will, nevertheless, show us much better than can any definition that can be framed what is the range and what the character of the work of the engineer.

Whenever a structure is to be erected, be it a bridge, a breakwater, a furnace, a tank, or a building, or be it what it may, in order that it should answer its intended purpose it must be erected in accordance with correct engineering principles; and the same is of course true of machinery. Regard must be had to its strength, to its stiffness, and to the efficiency and economy with which it can perform its functions.

Having discussed the nature and the range of the work of the engineer, we are now prepared to consider what kind of an education should be given to a young man who is to make engineering his life work, and this I shall proceed to discuss in the next lecture.

[*To be concluded.*]

THIN FILMS OF GOLD.

One of the interesting exhibits made at the recent *conversazione* of the Royal Society, held June 13, 1894, was that of Mr. J. W. Swan, F.R.S., who presented a number of specimens of leaves of gold of extreme thinness, which had been prepared by the process of electro-deposition. From a brief notice of the exhibit, published in London *Nature*, it appears that it represented an attempt by Mr. Swan, to produce gold leaf by electro-chemical, instead of mechanical means. "The leaves were prepared by depositing a thin film of gold on a highly polished and extremely thin electro-copper deposit. The copper was then dissolved by perchloride of iron, leaving the gold in a very attenuated condition. The leaves were approximately four-millionths of an inch thick, and some of them mounted on glass showed the transparency of gold very perfectly when a lighted lamp was looked at through them."

It will doubtless prove somewhat of a surprise to Mr. Swan, to learn that identically the same method of procedure for the production of films of metal of extreme tenuity was described and illustrated by Mr. A. E. Outerbridge, Jr., in a lecture delivered before the Franklin Institute in 1877, an abstract of which was published in the *Journal*.* At the stated meeting of the Institute held May 16, 1877, the then resident Secretary, the late Mr. J. B. Knight, made reference in his monthly report to the thin gold films produced by Mr. Outerbridge in the following terms:†

> *Transparent Gold.*—In the course of a lecture on gold, delivered before the Franklin Institute, on February 27th last, Mr. A. E. Outerbridge, Jr., of the Assay Department of the Mint in this city, gave an account of some experiments he had made, with the view of ascertaining how thin a film of gold was necessary to produce a fine gold color.
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> The plan adopted was as follows: From a sheet of copper rolled down to a thickness of $\frac{5}{1000}$ of an inch, he cut a strip 2½ x 4 inches. This strip,

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* *Vide Jour Frank Inst.*, ciii, 284.

† *Vide Jour. Frank. Inst.*, ciii, 369.

containing 20 square inches of surface, after being carefully cleaned and burnished, was weighed on a delicate assay balance. Sufficient gold to produce a fine gold color was then deposited on it by means of the battery; the strip was then dried without rubbing, and re-weighed, and found to have gained $\frac{1}{10}$ of a grain, thus showing that one grain of gold can, by this method, be made to cover 200 square inches, as compared to 75 square inches by beating.

By calculation, based on the weight of a cubic inch of pure gold, the thickness of the deposited film was ascertained to be $\frac{1}{980100}$ of an inch, as against $\frac{1}{367650}$ for the beaten film.

An examination under the microscope showed the film to be continuous and not deposited in spots, the whole surface presenting the appearance of pure gold.

Not being satisfied, however, with this proof, and desiring to examine the film by transmitted light, Mr. Outerbridge has since tried several methods for separating the film from the copper, and the following one has proved entirely successful.

The gold plating was removed from one side of the copper strip, and by immersing small pieces in weak nitric acid for several days, the copper was entirely dissolved, leaving the films of gold, intact, floating on the surface of the liquid. These were collected on strips of glass, to which they adhered on drying, and the image of one of them is here projected on the screen, by means of the gas microscope.

You will observe that it is entirely continuous, of the characteristic bright green color, and very transparent, as is shown by placing this slide of diatoms behind the film. By changing the position of the instrument, and throwing the image of the film on the screen by means of reflected light, as is here done, you will see its true gold color.

Mr. Outerbridge has continued his experiments, and, by the same processes, has succeeded in producing continuous films, which he determined to be only the $\frac{1}{2798000}$ of an inch in thickness, or 10,584 times thinner than an ordinary sheet of printing-paper, or 60 times less than a single undulation of green light. The weight of gold covering 20 square inches is, in this case, $\frac{35}{1000}$ of a grain; one grain being sufficient to cover nearly 4 square feet of copper.

As you see, the film is perfectly transparent and continuous, even in thickness, and presents all the characteristics of the one shown before. That a portion of the image appears darker, is due to superposed films, the intensity of the green color being proportioned to the thickness through which the light passes. * * * *

It may be stated, in conclusion, that the mode of procedure above described was patented by its author* under the title "Manufacture of Metallic Leaf." In his patent the inventor describes, as "a new and improved method of manufacturing gold leaf, silver leaf and other metallic leaf," the above-named method of electrical deposition. As suitable mediums to support his films, he mentions copper in thin sheets, and paper, shellac, wax, etc., made conductive upon the surface which is to receive the deposit.

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* U. S. Patent, 198,209, Dec. 18, 1877.

For removing the deposited film from copper and paper, Mr. Outerbridge describes the use of a bath of dilute nitric acid, or of perchloride of iron. In the case of the shellac, wax, etc., alcohol, benzine and other solvents are referred to.

While they detract neither from the interest nor genuineness of Mr. Swan's work, these circumstances are recalled in justice to Mr. Outerbridge, to whom priority undoubtedly is due.

W.

DRILLING FOR OIL AND NATURAL GAS IN THE VICINITY OF PHILADELPHIA.*

By Oscar C. S. Carter,
Professor of Geology and Mineralogy, Central High School, Philadelphia.

There have been several attempts made recently to drill for oil and natural gas near Philadelphia, notwithstanding warnings of failure from scientific experts. There seems to be a kind of fascination and an air of mystery in searching for gold, silver, oil or natural gas, which, apart from their value, lead men to spend much money and time in prospecting localities, which have never yielded anything in the past, and, from a geological standpoint, will never yield anything valuable in the future. True it is, beyond all doubt, that oil has been found in the older as well as the newer rocks, and nearly every geological horizon from the silurian up to and including the tertiary has yielded oil. It is not, however, evenly distributed through all formations. The silurian, devonian and tertiary rocks have yielded most of the oil of the world. It was formerly thought that the devonian rocks were the oldest that would yield oil, but when gas was discovered in the Findlay field and oil in the

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* Read before the Chemical Section, June 19, 1894.

Lima belt in Ohio, in 1886, it brought the limit of the oil-bearing rocks down into the lower silurian formation. The oil of the Lima belt was found in the Trenton limestone, not very far distant in a geological sense from the archæan granite. This was a great surprise to many who did not expect oil would be found in such a low horizon near the bed rock of the continent. The Trenton limestone of Ohio is now regarded as one of the most important sources of oil and natural gas in the world. In Indiana, in July, 1886, the combined flow of all the wells from actual testing and estimates was found to be 500,000,000 cubic feet of gas per day. Many of the gas wells have averaged 1,000,000 cubic feet per day. The Karg well is the largest of the Findlay district, and it is estimated that 1,500,000,000 cubic feet of gas from this well escaped utilization and were entirely wasted. In many small towns, over 700,000 cubic feet per day were wasted in working up booms and furthering real estate schemes. Laws have been framed for every conceivable purpose, and the rights of man are zealously guarded, but nothing has been done to prevent the criminal waste of Nature's richest gifts, which, in a few years, will exist only in history. The oil of the Trenton field is equally abundant; many of the wells have yielded 1,000 barrels per day, and the product of the Lima belt for 1888 was 9,682,683 barrels of oil. The Lima oil is black and heavy and contains sulphur compounds which have a disagreeable odor and are removed with difficulty in the refining process. Particular mention has been made of this Trenton limestone, because we have the silurian limestone, of which the Trenton is a part, within a few miles of Philadelphia.

The Schuylkill or Chester Valley is an immense trough of jointed, fissured and steeply dipping limestone. If oil or gas ever existed there it escaped ages ago. The limestone of Ohio, on the contrary, is as level as a floor, the slope being but two or three feet to the mile. It must also be remembered that oil at Lima is found at a depth of 1,300 feet. It takes sixty days to drill a well, while the silurian limestone near Philadelphia is found on the surface outcropping along the Schuylkill at angles of from 45° to 60° for a distance of four miles below Norristown. Ever since Trenton oil has been found the sound of the drill has been heard in every State from New England to the Rocky Mountains, searching for this new oil and gas rock of Ohio. It is easily reached in many States, but does not contain oil, because the conditions are not the same. The Trenton limestone is only productive in the part which is a dolomite or magnesian limestone; the non-magnesian limestone has not yielded oil. Besides being horizontal and porous, it must be favorably situated to the surrounding strata for the accumulation of oil.

One of the most interesting experimental wells for natural gas or oil was drilled at Fitzwatertown, twelve miles from Philadelphia. There were stories told in the past by the farmers of the vicinity of a slight scum of oil appearing on the water in the spring-houses, and that bubbles of gas would come up through the water of the creeks, so that some were not surprised when operations were begun. Fitzwatertown is a country village on the Limestone Pike; the nearest railroad station is Edge Hill, on the Bethlehem branch of the Reading Railroad. The drilling was commenced by a stock company, and hundreds of acres were leased. The sinking of the well began on an eight-acre farm owned by Elijah Lukens. *The Philadelphia Inquirer*, of February 16, 1890, says: "The drillers worked day and night from that time onward; many precautions to keep the work secret were inaugurated. The rig was boarded in, and a rudely painted sign, nailed on the outside, announced that without a permit from the president, admission could not be obtained. The story the gossips talked about was this: Three weeks ago the driller, James H. Moore, and foreman Sclocomb noticed a regular puff, puff, whenever the drill was lifted, experience in the Bradford County fields led them to believe that natural gas had been struck, though at a depth of but 400 feet they regarded this as improbable. A sort of cap or reservoir arrangement, constructed of tin and topped with a key and burner, was placed over the hole to allow an accumulation of gas. In half an hour the key was turned and a match applied to the burner; a steady mellow flame resulted when the key was half turned on. At full head the pressure was so great that the flame was extinguished. The company, though jubilant at the success already attained made another test with a larger reservoir, and the result more than satisfied their expectations."

I visited this well May 24, 1890. Three men were at work with a regular oil well derrick and apparatus and a small engine of fifteen-horse power. In drilling, they reached water or quicksand at a depth of ten feet; then limestone was reached. The strata here are nearly vertical, and much trouble was experienced as pieces broke off and fell down the well. There was much difficulty in keeping the drill hole straight. It is much easier to drill horizontal strata.

The drill passed through 330 feet of silurian limestone before the so-called Potsdam sandstone was struck; the well was then probably about 460 feet deep. An examination of the drillings showed me that the drill was then passing through the so-called Potsdam sandstone, which has never yielded oil or gas in any locality; about 130 feet of Potsdam had been drilled. The well was cased with iron pipe to a depth of 330 feet or through the limestone. It is a wet well; the water rises to within ten feet of the surface. The sand pump was put down that afternoon, and the well cleaned and a new drill put on, but not the slightest odor or indication of gas could be observed at the mouth of the well. The most interesting feature about the place was a pond of clear and sparkling water about twelve feet distant from the derrick; the sand or quicksand in the bottom was in continual motion. One of the workmen procured a pole, and on pushing it down through the sand bubbles of gas came up by the hundred. There was a small gasometer of ten gallons capacity floating in the pond, it was furnished with a stop-cock. On turning this I noticed an odor of gas, and on lighting it found it burned with an almost invisible flame. You could scarcely, in fact, see it in daylight, but on approaching a splinter of wood to it the wood at once took fire.

It may have been marsh gas. No analysis was ever made. There seemed to be no decomposing vegetable matter in the pond. The drillers were very sick of their work. After they had drilled 550 feet they left, but the contract stipulated that they were to drill 720 feet before stopping. If they stopped before that depth was reached, then the company was to have the use of his plant one day for each foot that remained to be drilled. The plant was finally sold at sheriff's sale, although the company was entitled to the use of it for 170 days. Nothing further was done, and the well was abandoned. Not long after the failure of the well at Fitzwatertown, a deep well was drilled for oil and gas in Bucks County, not far from Philadelphia, in the new red sandstone of triassic age. This well was over 1,000 feet deep, and passed through beds of sandstone, red shale and slates. A bed of black slate, containing coaly matter, was encountered. This is the same bed of slate that was met with in drilling all the artesian wells at Lansdale, Montgomery County, Pa., in the new red sandstone (see *Franklin Institute Journal*, September, 1893). The same bed of coaly slate was passed through in drilling the Duffield well several miles distant, on the Stony Creek Railroad (see *Proceedings American Philosophical Society*, Vol. XXIX, May 25, 1891). Another experimental well for oil and gas was drilled at Valley Forge, in the Potsdam sandstone, with the usual result.

Not long afterward, there was reported a find of crude petroleum near Doylestown, Bucks County. It was announced that what seemed to be a rich crude oil was oozing out of the ground on the small farm of William Eisenhart. While Mr. Eisenhart was working in his cornfield, he came upon a pool of water covered with a heavy scum of oily substance. He found that a stream of oily fluid was oozing out of the ground and covering considerable space, finally finding its way to Cook's Run, a small stream running near by. Several citizens from Doylestown visited the place of the supposed rich discovery, and were outspoken in their belief that oil exists in paying quantities at no great distance below the surface. Mr. Eisenhart sent me a sample of this water for analysis. Qualitative tests showed much iron and organic matter, and a black substance held in suspension, but not the slightest trace of oil was present.

State Geologist Lesley tersely discusses the question where oil and gas will not be found in Pennsylvania, in the following words: "First of all, there can be no gas stored up in the oldest rocks. This at once settles the question in the negative for the whole southeastern third of the State. To bore for gas in Bucks, Montgomery, Philadelphia, Chester, Delaware, Lancaster, York or Adams Counties would be simply absurd. Secondly, there can be no gas left underground where the old rocks have been turned upon edge and overturned, fractured and re-cemented, faulted and disturbed in a thousand ways. If there ever was any, it has long since found innumerable ways of escape into the atmosphere. This settles the question in the negative for all the counties of the great valley—Northampton, Lehigh, Berks, Lebanon, Dauphin, Cumberland and Franklin, as any one can see by looking at the present condition of their limestone, slate and sandstone formations. Thirdly, there is not the least chance that any gas is left underground in the greatly folded, faulted, crushed and hardened formations of the middle belt of the State—Carbon, Schuylkill, Lehigh, Luzerne, Columbia, Montour, Northumberland, Union, Snyder, Lycoming, Perry, Juniata, Mifflin, Centre, Clinton, Huntingdon, Blair, Bedford and Fulton Counties. Where the oil and gas rocks rise to the surface in these counties, as they do in a thousand places, they show that all their oil and gas has escaped long ago. Fourthly, where the rock formations lie pretty flat and have remained nearly undisturbed over extensive areas, as in Wayne and Susquehanna, parts of Pike and Lackawanna, Wyoming, Bradford, Tioga, Potter and all the counties west of the Allegheny Mountains—there is always a chance of finding gas (if not oil) at some depth beneath the surface, determined by the particular formation which appears at the surface; but, as yet, we have no satisfactory evidence of the existence of quantities of rock gas in any of these counties east of Potter. Fifthly, wherever the bituminous coal beds have been changed into anthracite or semi-bituminous coal, it is reasonable to suppose that the same agency which produced the change, whatever it was, must have acted upon the whole column of formations, including any possible gas rock at any depth. Sixthly, wherever rock-oil has been found, there, and in the surrounding region, rock-gas is sure to exist. In the deep Erie well, the Trenton was reached. In the Canada well on the south shore of Lake Ontario, the Trenton was pierced. Several wells in New York State penetrated it. In no case has there been any profitable return of either oil or gas. And if this happens under the exceptionally good conditions in central and western New York, where the formation is very fossiliferous, lies nearly flat and can be easily reached, what chance is there of success for those who bore in the uplifted and dislocated and poorly fossiliferous strata of Pennsylvania? Where the Trenton is brought to the surface, it shows plainly that whatever petroleum or rock-gas was once distilled from its fossil corals and shells has, ages ago, escaped from it."

ON THE INTERACTION OF BORAX, CARBONATES AND POLYHYDRIC ALCOHOLS; ALSO ON THE COMPOSITION OF BORAX.*

BY LYMAN F. KEBLER.

It was the profund observation of Lord Bacon that "In all generations and transformations of bodies, we should inquire what is added, what remains and what is lost; what is united and what is separated." This is the true character of inductive philosophy, careful observation and rigid analysis. These sentiments are applicable to these questions as well as to the many difficult problems constantly inviting our sober thoughts.

From statements made in certain† lines of literature we are led to infer that on mixing *borax*, *sodium bicarbonate* and glycerol, a certain chemical reaction ensues in which there are formed normal sodium carbonate and carbon dioxide. This is equivalent to saying that there is no interaction, as far as the carbonate is concerned, when a normal alkaline carbonate is employed instead of the acid carbonate.

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* Read at the meeting of the Chemical Section held June 19, 1894.

† National Dispensatory, 5th ed., p. 1455.

Recently, the writer had occasion to establish the presence or absence of sodium bicarbonate as an adulterant in a sample of borax. After having exhausted all the available tests of reputed value without obtaining definite results, recourse was sought in the above reaction but it was soon discovered that the same reaction resulted with the normal carbonate, except that it was less energetic. Being somewhat surprised at this unexpected phenomenon the writer made an investigation and soon found that the same result had been reported by C. Jehn* some six years previously.

D. Klein† and the same year A. Senier‡ and A. J. G. Lowe showed that an acid reaction resulted when borax is dissolved in glycerol. W. R. Dunstan§ also made a comprehensive report on the reaction of polyhydric alcohols and borax. The acid reaction results not only with the polyhydric alcohol glycerol, but also with many other polyhydric alcohols, as mannitol, erythrol, levulose, dextrose, glucose, α-galactose and β-galactose, Undoubtedly many other polyhydric alcohols, as sucrose, raffinose, lactose, dulcitol, quercite, etc., would produce the same reaction if subjected to the proper conditions.

It is reported that borax is decomposed even by water, for Rose‖ has shown that strong solutions of this salt give precipitates of silver borate, while dilute solutions act like an alkali, precipitating argentic oxide.

The acidity is unquestionably due to the transformation of the borax into sodium metaborate and boric anhydride, the latter uniting with water to form boric acid. As significant evidence substantiating the above statement, it may be noted that no acid reaction results in the absence of water, for on using anhydrous borax, anhydrous glycerol and elevating the temperature so as to expel the water formed during the reaction, no acid reaction results.

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* 1888, Arch. der Phar., (III), **26,** 495; Am. J. Pharm., **60,** 455.

† 1878, Bull. Soc. Chim., **29,** 195; Comp. rend., **86,** 826.

‡ 1878, Pharm. J. Trans., (III), **8,** 819.

§ 1883, Pharm. J. Trans., (3), **13,** 256; Am. J. Pharm., **55,** 447.

‖ Mendeléeff's Principles of Chemistry, Eng. Ed. Vol. 2, p. 60.

Confirmatory evidence of the correctness of this view of the composition of borax may be found in the formation of tetraboric acid. When orthoboric acid is heated, there are formed at 100° C. metaboric acid and water ($H_3BO_3 = HBO_2 + H_2O$); at 160°C. it yields tetraboric acid and water ($4H_3BO_3 = H_2B_4O_7 + 5H_2O$); at a still higher temperature all the water is eliminated and boric anhydride is formed ($H_2B_4O_7 = 2B_2O_3 + H_2O$).

Tetraboric acid is the intermediate compound from which only a portion of the water has been eliminated; that is, it is neither metaboric acid nor boric anhydride, but a mixture of the two. In that borax is a salt of tetraboric acid, it must necessarily share an analagous composition. Direct evidence that borax is so constituted is wanting, but indirect evidence appears to be ample.

The avidity of boric acid is unity when nitric acid is taken as 100. Boric acid displaces carbonic acid, and *vice versa*, depending on the conditions; consequently, the avidity of carbonic acid must be nearly unity.

It appears to be well established that the acidity above referred to is due to boric acid; therefore, all carbonates transposable by this acid will evolve carbon dioxide with the simultaneous formation of sodium metaborate and sodium orthoborate when mixed with borax and glycerol.

The following equations present the facts in a most lucid manner:

(1) $2C_3H_5(OH)_3 + Na_2B_4O_7 = 2C_3H_5(OH)_3 + NaBO_2 + 3H_2O$.

(2) $2C_3H_5(OH)_3 + Na_2B_4O_7 + 3H_2O = 2C_3H_5(OH)_3 + 2H_3BO_3 + 2NaBO_2$.

(3) $C_3H_5BO_3 + 3H_2O = C_3H_5(O_3H)_3 + H_2 = 2C_3\ BO_3$.

(4) $3Na_2CO_3 + 2H_3BO_3 = 2Na_3BO_3 + 3CO_2 + 3H_2O$.

The first equation represents the reaction when water is absent, that which is formed being expelled by heat; the second, when water is present; the third the action of water on boroglycerol; and the last simply the action of boric acid on an alkaline carbonate. When calcined sodium carbonate is fused with boric acid ordinary borax is produced.

Boric acid may replace successively the hydroxyl groups of polyhydric alcohols forming mono-, di-, tri- and poly- products, therefore, we may have simultaneously formed one or more products of transformation.

Glycerol here evidently plays the part of a catalytic, as sulphuric acid does in the formation of ether from alcohol. Thus alcohol is not converted into ether and water by boiling alone, but is so converted by boiling with sulphuric acid. The catalytic function of polyhydric alcohols is very clearly typified in the action of glycerol on borax. The quantity of glycerol is found to have neither increased nor decreased, but has, nevertheless, taken part in the several reactions, which would not have resulted but for the presence of glycerol or some other polyhydric alcohol, or of an aldehyde.

Catalysis has been of no small service in advancing stereometric chemistry through the agency of micro-organisms so admirably adapted for mesotomising various asymmetric carbon compounds, as the amylic alcohols, propylene glycol, mandelic acid, glyceric acid and many others through the agency of organized ferments. Among these, *Penicillium glauca* and *Bacterium termo* have been of especial service. Unfortunately we do not possess, in the inorganic field, an invaluable polariscope, which will reveal to us at a glance the ultimate transformations of a body under given conditions.

LABORATORY SMITH, KLINE AND FRENCH CO., 306 CHERRY STREET, PHILADELPHIA.

BOOK NOTICES.

Helical Gears: a practical treatise. By a foreman pattern-maker. New York: Macmillan & Co. 1894. Price, $2.00.

The author of this book elaborates in detail the method of making the patterns of helical gear wheels, and of the tooth blocks to be used in gear-moulding machines, and gives many valuable practical hints.

The enumerated advantages of helical gears can, however, properly be claimed only if the teeth are accurately divided and correctly formed. But inasmuch as gear wheels with cast teeth are far from accurate, the claim of superiority should accordingly be qualified, especially since by reason of the vastly greater difficulty of making them, cast helical gears are, as a rule, less accurate than ordinary gear wheels. But as experience indicates that in some instances helical gears, when carefully made, give better results than others, the book will be a valuable guide for those who are in the position of having to make the patterns. H. B.

Standard Arithmetic. By William J. Milne. New York: American Book Company. 1893. 12mo. Price, 65 cents.

In this book the fundamental operations and principal commercial applications of arithmetic are clearly set forth.

We would call attention to the definitions of the terms unit and number, which, as they stand, are manifestly incomplete. If scientific definitions of these terms are too difficult for the pupil to understand when he begins the book, rather give him no definitions at all, but defer them until a more advanced part of the work.

This criticism does not apply to this book alone; it applies equally to a large number; in fact, to most of the books on elementary arithmetic in use in this country. But one looks to the new books to remove these old objections.

The work contains a large number of well-selected examples, designed, as the author states in his preface, to secure skill in calculation, and comprehension of methods.

On the whole, it compares favorably with the works on arithmetic in common use. E. A. P.

American Mental Arithmetic. By Prof. M. A. Bailey. New York: American Book Company. 1893. 12mo. Price, 35 cents.

We have in this book an excellent drill book in the subjects usually included in a work on elementary arithmetic. The use of parallel columns, one containing statements and the other illustrations of them, is to be commended, since it associates as closely as possible the principles enunciated with explanations of them, still preserving continuity of statement.

We are pleased to see so large a space devoted to the metric system, as the importance of an early knowledge of it cannot be overestimated. In this connection, however, we desire to point out an error in the definition of the meter. It has nothing to do with the dimensions of the earth, but is simply the length of a certain bar of platinum at 0° Centigrade.

It is to be regretted that the author, in accord with recent tendencies in teaching arithmetic, has dismissed the subject of proportion in a single page. The author is to be congratulated for introducing a few problems involving the notion of density. A great deal of arithmetic, as well as a great deal of elementary physics, can be well taught by properly selected examples of this kind. E. A. P.

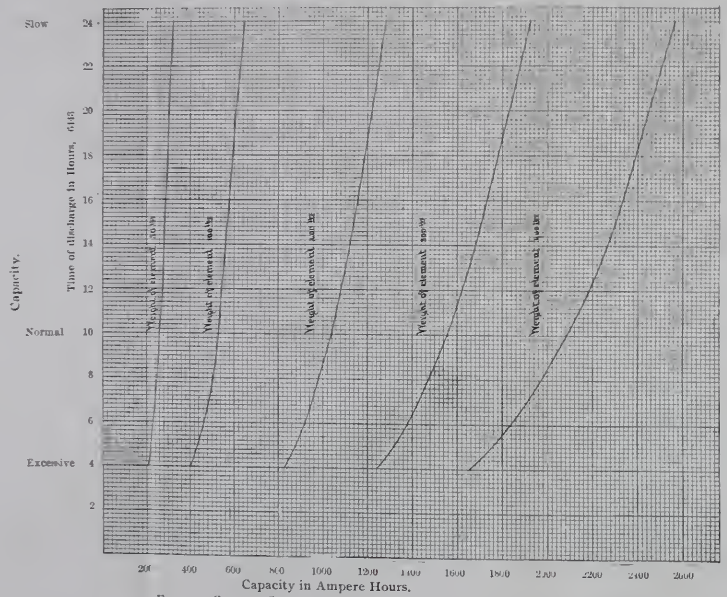

FIG. 3.—CURVES SHOWING CAPACITY AT DIFFERENT RATES OF DISCHARGE.

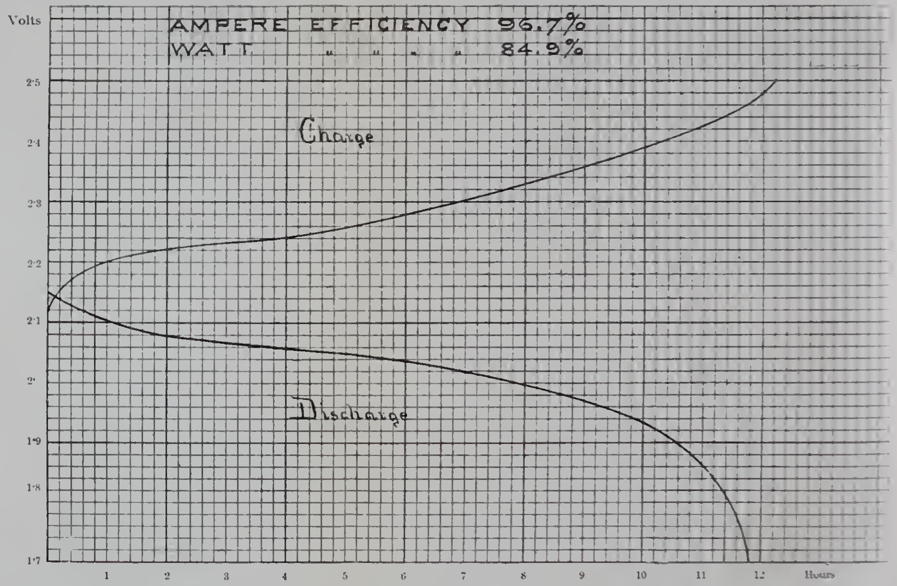

FIG. 4.—CURVES SHOWING E. M. F. DURING CHARGE AND DISCHARGE.

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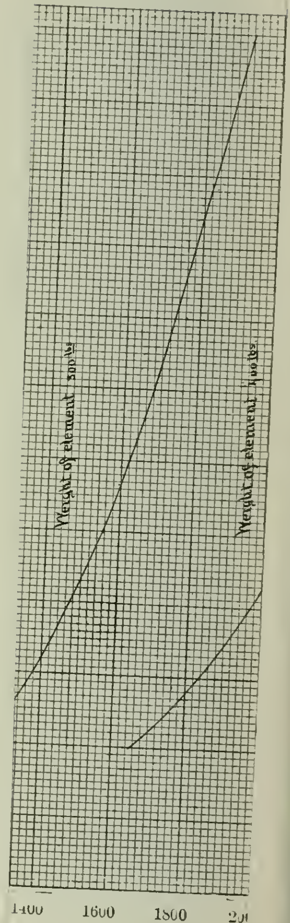

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AT DIFFERENT RATES

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE CHLORIDE ELECTRICAL STORAGE BATTERY.

[*Being the report of the Committee on Science and the Arts on the invention of Clement Payen*].

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, March 29, 1894.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the "Chloride Electrical Storage Battery," finds as follows:

The sub-committee appointed to conduct this investigation has had this battery under careful consideration for a number of months, and has investigated the several features which are claimed to give it merit. During the larger portion of the time a number of cells have been in possession of the committee, and have been placed upon a regular working circuit under the control of one of the committee's members, where they have been subjected to exactly the same usage as a number of other storage cells of other makers and of the same size, so that opportunity was thus given to obtain the results of the performance of the chloride storage battery in regular use, which is ultimately the final test by which the utility of all inventions and improvements must be measured.

The results of this examination have led to the opinion that this battery embodies certain features of construction which prove it, both theoretically and as verified by use, to be a distinct improvement over hitherto known forms of storage batteries. In order to fully appreciate these features of improvement, it will be necessary to recapitulate, briefly, a few well-known facts regarding storage batteries in general.

In all lead storage batteries, one of the objects desired is to obtain a large lead surface for small mass, as the capacity and discharge rates are strictly proportional to the amount of surface involved. This necessary maximum of surface has hitherto been obtained in one of two ways. The earlier way was to slowly eat out the lead plates by electrolysis until they had attained the requisite spongy condition, an affair of some time and expense. The later way—and the one which is generally practiced—is to cast a frame of lead, with raised right-angled ribs on each side, thus forming little depressed squares, or to punch a lead plate full of holes, which squares or holes are then filled with a pasty mixture of red oxide of lead in positive plates, and with litharge in negatives.

For several reasons cells made in this way have always given more or less trouble in service. In the first place, after continued use or during heavy discharges, a greater or less amount of mechanical disintegration of the positive plates would often take place, small fragments of lead and lead oxide dropping down between the positives and negatives, short-circuiting them and often causing further and more serious break-up, buckling and sulphating. Even when these particles are prevented from falling, their mechanical looseness causes poor contact with the supporting lead frame, thus entailing increased internal resistance and heating with diminished output. This disintegration appears to be due largely to the fact that the lead oxide paste placed in the holes, is a mechanical rather than a chemical mixture, and hence that in changing from PbO_2 to $PbSO_4$ during the action of the cell, the molecules being only related to one another in a fortuitous manner, are easily broken up and thrust apart in the change of volume attending the chemical action. This, of course, seriously limits the life of a battery, and its utility for public service.

In the chloride battery, it is claimed and the committee's investigations go to confirm the correctness of the claim, that the method of construction is such that this disintegration is far less liable to occur. This mode of construction is as follows:

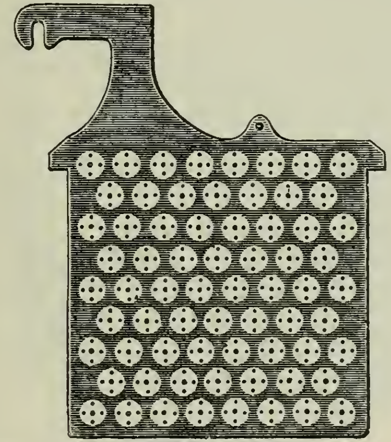

FIG. 1.—Type "E." Size, 7¾ x 7¾ inches.

Instead of cementing lead oxide paste into or against a lead framing in order to obtain the necessary active material, the latter is obtained by a strictly chemical process. Lead chloride is taken, mixed with a given proportion of zinc chloride, and this mixture is then fused and cast in small squares in suitable moulds. When thus cast, the product is of whitish color and vitreous character, being quite brittle.

For the negative plates, these blocks are about ¾ inch square and $\frac{5}{16}$ inch thick, and are cast in groups of four, these groups being united by portions, having, say, $\frac{3}{32}$ to $\frac{1}{8}$ inch thickness. For positives, the fused mass is cast in separate lozenges, each lozenge having a bevelled V-shaped periphery. These cut squares or lozenges are then placed in a suitable mould, and a molten mixture of lead and antimony, in proper proportions, is cast about them under high pressure, thus fixing them securely in a firm lead framing of somewhat more than the usual density. (The feature of casting under pressure is an improvement in manufacture, due to Mr. H. Lloyd, who is connected with the American makers, and the process is protected by patents granted to him). The connecting sheets of the squares making up a group and the V-shaped bevel of the lozenge serve to make their solidity of fixation exceedingly good.

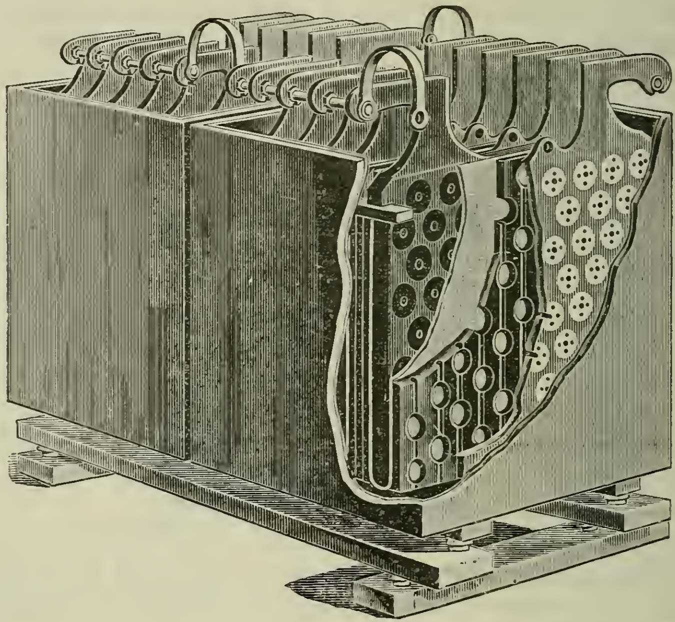

FIG. 2.

The frameworks containing the chloride castings are then placed in a dilute solution of zinc chloride, together with plates of zinc, the frames and zinc plates being alternated with one another and in metallic contact. This combination is the equivalent of a primary battery "dead short-circuited." The chemical reactions which occur, result in the removal of the zinc chloride and the chlorine of the lead, and there remains finally the dense framing containing squares or lozenges of spongy lead, which plates are then "formed" in, practically, the usual manner.

If a section of the spongy lead thus made, be examined, it is found that the metal is in a crystalline condition, and that the crystals are all uniformly arranged with their longer axes perpendicular to the surface of the plate. This provides interstices, so that the changes of volume occurring in the chemical reactions of electrolysis, may take place without exerting lateral pressure upon the crystals, or otherwise crowding them into a condition of break-up. These crystals are not, of course, mechanically and irregularly bound together, but are related to one another according to the laws of molecular formation, and are, consequently, much more strongly bound together than if they had been mechanically combined.

Furthermore, this crystalline structure presents the maximum obtainable surface for the given mass, an infinite number of inter-crystallic channels passing all through the material and the entire plate being of the same thoroughly spongy consistency, except in those small portions where the continuous lead framing is encountered.

The effect of this extreme porosity and surface area is to give the battery a maximum capacity for a given weight and size of cell, an item of great importance when considered with reference to the demands of traction. Very heavy discharges also can be taken from this battery, owing to the interstices between the crystals permitting changes of volume to occur without mechanical violence to the structure.

While the method of construction just described seems to accomplish its anti-disintegrating function perfectly, it has been thought best by the manufacturers, in order that there shall be no doubt about the matter, to introduce between the plates a thin sheet of acid-proof fabric, so that any small particles which might fall away, could not make metallic contact with two adjacent plates and thus short-circuit the cell. The fabric chosen for this purpose is woven asbestos cloth. It might be thought that the introduction of this asbestos would considerably increase the internal resistance of the cell, but the fact is otherwise, the resistance of the cell being not appreciably higher than that of other lead cells.

This is undoubtedly due to the fact that the larger part of the resistance of most lead cells is that caused by poor contact between the lead framing and the paste placed in it. In the chloride battery this contact is exceptionally good, owing to the pastilles of chloride being so firmly bound by the framing cast under pressure as to compensate for any resistance due to the asbestos.

These batteries are, and have been for several years, operating successfully and in very large numbers in the city of Paris as a source of current for lighting purposes. A large plant has been in operation in this city in the building of the Provident Life and Trust Company for a year past, and a very large one has been installed at the station of the Germantown Electric Light Company, where it is said to have given, thus far, entire satisfaction.

The manufacture of this battery is protected by a large number of patents of the United States and of foreign countries, a list of which is hereto appended.* The essential features of the process of manufacture, however, are covered by the patents granted to Mr. Clement Payen.

Believing that this battery is a noteworthy and meritorious improvement upon many other forms of lead battery, tending to greater durability, greater capacity without increase of weight, and making possible heavier discharges without injury, the Institute, therefore, recommends the award of the John Scott Legacy Premium and Medal to to Clement Payen, the inventor.

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* Accessible for reference in the records of the Committee on Science and the Arts.

Adopted at a meeting of the Committee on Science and the Arts, held Wednesday, June 28, 1894.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

APPENDIX.

The accompanying illustrations are introduced by way of explanation of the text of the foregoing report. *Fig. 1* gives a clear idea of the appearance and shape of the plates. *Fig. 2* represents two cells of the chloride accumulator with a portion of the tank broken away to exhibit the disposition of the individual elements. The cut also shows clearly the manner of connecting up the elements and cells.

The curves, *Figs. 3* and *4*, shown herewith, exhibit the working capacity and electrical efficiency of the chloride accumulator, and their interpretation will present no difficulties to the electrician.

WURTS' LIGHTNING ARRESTERS FOR THE PROTECTION OF ELECTRIC LIGHTING AND POWER CIRCUITS.

[*Being the report of the Committee on Science and the Arts on the improvements in Lightning Arresters invented by Alexander Jay Wurts.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 3, 1894.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating "Wurts' Lightning Arresters," finds as follows:

The Institute, through a sub-committee appointed for the purpose, has carefully examined the claims set forth for these inventions as embodied in specimen arresters submitted, copies of patents granted and literature relating thereto. A considerable number of reports of effective operation have also been examined.

The various arresters produced by Mr. Wurts are intended for the protection of electric lighting and power circuits from direct and indirect damage from lightning discharges, and Mr. Wurtz has, apparently, studied this question in a scientific and very exhaustive manner.

With but few exceptions, all lightning arresters commonly used, up to the inventions of Mr. Wurts, have been based upon the fact that static discharges generally tend to "ground" by the shortest distance—even when obliged, in order to do this, to jump a considerable "air gap"—in preference to taking a longer path over a much lower resistance. Such arresters, therefore, have been essentially nothing more than two points or sets of points, one being "grounded" and the other connected to one or both legs of the circuit to be protected.

An arrester of this kind, while often affording a release from the static charge, would also allow the dynamo current to follow upon the arc so produced, thus producing either short-circuit or a dangerous "ground," and in both cases causing an interruption of the main working circuit. Hence, the more improved arresters of this type were so constructed as to break this dynamo arc as soon as possible. This is easily seen to be a remedy rather than a preventive.

Mr. Wurts perceived this fact and set himself the problem of constructing an arrester in which the dynamo arc could not start, rather than one which would break the arc when started. As far as can be judged from recorded data, he has succeeded in solving the problem in a very efficient manner, both for alternating and direct currents. We shall consider the separate forms separately.

The "Non-arcing" Metal Alternating Arrester.—This arrester, although the simplest in construction, is perhaps, the most notable of all Mr. Wurts' arresters. It consists simply of seven cylinders of metal, each one inch in diameter, and three inches long. These cylinders are mounted side by side, and separated from one another by $\frac{1}{64}$ of an inch. The central cylinder is joined to ground, and the two outside ones to the two legs of a 1,000-volt circuit. They are knurled on their surfaces and fixed so that they can individually be rotated upon their axes. When a static discharge takes place either from one side to ground, or from both sides simultaneously, it is found that the flash is instantaneous and is not followed by an arc, while the temporary change in current value in the main circuit is too small to be easily appreciable. After-examination of the cylinders exhibits a slight black pit or burn where the discharge has passed.

Mr. Wurts has found that this non-arcing of the arrester is a property which is confined to certain particular metals and combinations of those metals. The most common are zinc and antimony. With these metals it is impossible to start and continue an arc when they are separated by an air gap of about $\frac{1}{64}$ of an inch. With longer gaps, *e. g.*, half an inch, vicious arcing is said to occur—a most peculiar fact.

Various explanations are offered to account for this non-arcing property, the one most generally accepted being that the metals immediately produce a non-conducting oxide vapor, over which the current cannot pass. The discovery and first use of these non-arcing metals is claimed by Mr. Wurts, and these claims are acknowledged by the issue to him of broad United States patents.

The Railway Lightning Arrester.—The non-arcing arrester just described is not suitable for any but alternating circuits. For electric railway circuits, a different arrester has therefore been devised. This consists essentially of a spark-gap joined by a non-inductive high resistance made of charred wood. A cover is then placed on the arrangement, and acts as a suppressor of any conducting vapor which might tend to be produced upon discharge taking place. The high resistance, or more properly, the conducting film between the electrodes, seems to act as a wedge through the dielectric and over which discharges pass disruptably to earth, making a sharp sound similar to the crack of a teamster's whip. An arrester of this type submitted to the committee, and said to have been struck several hundred times, had suffered but little damage.

System of Protection for High Potential Circuits.—For the protection of circuits of high potential, Mr. Wurts has devised a system which consists in the placing at various points in the circuit of impedence coils of low resistance. These points, according to Mr. Wurts, become points of reflection for the high frequency surging which he considers the real form, as far as circuits are concerned, of lightning discharges. By means of these points of reflection, he conceives the electrical waves to be reflected back and broken up and eventually frittered away in the form of heat without actually getting to the generating of receiving apparatus at all. This form of protection, however, is not yet out of the experimental stage.

With the exception of the last described instrument the operative features of these various forms of arresters conform more closely to recognized laws than those of the devices previously known and used for the purpose. The instruments are cheaper to manufacture, and as far as the Institute has been able to ascertain, are very effective in preventing damage, and they protect without causing cessation operations.

In these respects, the Institute believes these inventions to be important improvements, and therefore recommends the award of the John Scott Legacy Premium and Medal to their originator, Alexander Jay Wurts, of Pittsburgh, Pa.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 2, 1894.

JOSEPH M. WILSON, *President*,
WM. H. WAHL, *Secretary*.

Countersigned by

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

THE CENTRIFUGAL PUMPING PLANT AT MARE ISLAND NAVY YARD, CALIFORNIA.

By John H. Cooper, M.E.

A marked departure in centrifugal pump building in this country was inaugurated in the year 1884. During this year an example of superb stone dock architecture was nearing completion, within the extended precincts of Mare Island Navy Yard, California.

For emptying this dock of its seven to nine millions of gallons of water, within the practical limits of time necessary to safely secure a vessel therein, there would be required an adequately proportioned pumping mechanism.

To this end proposals were issued by the United States Government for a plant to consist of a pair of centrifugal pumps having an aggregate average discharge of 80,000 gallons per minute and a drainage pump with an average delivery of 2,000 gallons per minute, together with the necessary pipes and valves to connect them with the suction wells of the dock and to the discharge culvert communicating with the river, including propelling engines, foundation plates for supporting them and full equipment for operating the same.

No general plans or details whatever were furnished; the plant was to be delivered and erected in a house to be prepared by the Government beside the dock, to which also steam would be conveyed from boilers furnished by the department.

When completely erected by the contractors the plant was then to be tested by a committee of experts appointed by the commandant of the yard.

This contract was awarded to the Southwark Foundry and Machine Company, of this city, and bears date July 31, 1884, at which time Mr. Joseph L. Ferrel was manager, and to the writer of this article, then chief engineer of the works, was entrusted the entire formulation of the design and the conception and arrangement of its details, in which latter he was ably assisted by Mr. T. H. Mirkil, Jr., who also erected and started the plant *in situ*.

Referring now to a general end elevation of the plant, as designed and erected for this dock, the main pumps *HH* will be noticed on foundation plates located considerably below the dock coping.

From the pump centers thirty-inch diameter breeches pipes *EE* descend to their joinings, with the horizontal forty-two-inch gate valves *FF* in their pits below the engine-room floor.

Extending beneath these will be seen the forty-two inch suction pipes *BB*, surrounded by flanges built in the deep concrete arches covering the suction conduits *JJ*. Through these conduits all the water from the dock flows into the suction pipes, to facilitate which the depressions *OO* were made immediately beneath their bell mouth inlets.

From the discharge ends of the pump casings, the water is conveyed through the rising bends *GG*, to the check valves, thence through the vertical forty-two inch gate valves *FF* into the discharge pipes *AA*, which are built into the heavy walls of the engine house, thence into the discharge conduit below the ground level, which receives the water from all the pumps and conducts it to the river.

The forty-two inch gate valves of the main pumps are steam-actuated, hydraulic-controlled, and are under the full command of the engineer at his stand by the throttle valves of the engines. They are also provided with starting screws turned by large hand-wheels to free the valves from their seats, to which they are liable to stick after long standing.

The check valves are supplied with visible index and supporting levers; they float upon the full stream of unobstructed water in their casings, flowing from their pumps when in normal action.

Each engine is directly connected to its own pump, but is independent of the other. The main pumps and engines are mounted upon attached bed-plates, as one firmly united and self-contained whole.

The steam cylinders of the main engines are 28 inches

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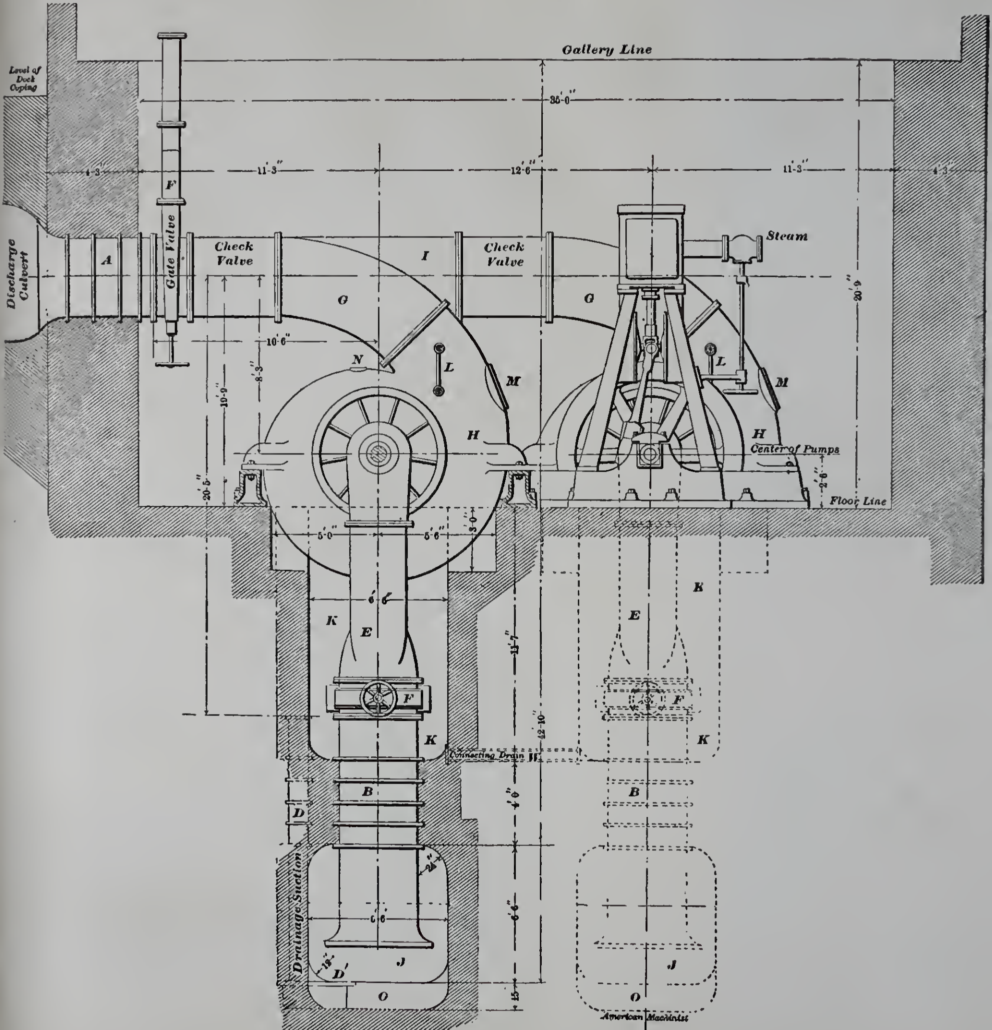

General End Elevation of the Centrifugal Pumping Plant at Mare Island Navy Yard, Cal.

diameter by 24 inches stroke; the drainage engine cylinder is 12 inches diameter by 10 inches stroke. These sizes were based upon the promised 50 pounds of steam per square inch.

The steam and manipulative equipment includes water gauges *LL* on the sides of the pump casings; steam charging ejectors on the summits of the same; hand adjusting steam cut-off valves and the usual automatic oilers; ladders into and foot-plates over the pits; man-holes for access to interiors, etc.

The pumping head of the main pumps varies from nothing at the start to about thirty-five feet at the finish.

The drainage pump, being used only for freeing the emptied dock of ordinary leakage, does all its work under the extreme head named, varying only from this by fluctuations of the tide without the dock and by slight changes of water level within the same.

Its suction pipe *D* is shown in place, rising from the pump box *D'*, covered by a grating at lowest level of the inlets *JJ*. A supplementary suction to the drainage pump relieves the pits *KK* of leakage, the two having a connecting drain pipe *W*.

In order to properly present the accomplished results of this initial centrifugal dock pumping plant, a reproduction of fitting paragraphs is made and here given, from the report of the Chief of the Bureau of Yards and Docks, on the occasion of its completion and first experimental trial. To these may very appropriately be added the concluding words of the Board on the accepted figures of the trials.

The writer is grateful for the unusual interest taken by the members of this Board in the reception and installation of this plant; the touch of a warm hand is manifest in the test as well as in the pen pictures given of its performance.

"During a pumping period of fifty-five minutes the dock had been emptied from the twenty-third to two inches above the sixth altar, containing 6,210,698 gallons, an average throughout of 112,922 gallons per minute. At one time, when the revolutions were increased to 160 per minute, the discharge was 137,797 gallons per minute; this is almost a river, and is hardly conceivable. After the pumps were stopped, on this occasion tests were made with each in succession as to the power of the injectors with which each is fitted to recharge the pumps.

"In practice it would be impossible to secure a vessel in the dock, so rapidly was the water removed at the time of trial, and it is without parallel in the world that so large a dock, with its 7,000,000 gallons of water, has been emptied in fifty-five minutes, and it is almost beyond belief. One pump will do all that is required to empty the dock in use, and then it will require sharp work to properly shore the vessel to replace the rapidly-receding water.

"Everything moved most admirably, and the performance of these immense machines was almost startling. By watching the water in the dock, it could be seen to lower bodily, and so rapidly that it could be detected by the eye without reference to any fixed point.

"The well which communicates with the suction tunnel was open and the water would rise and fall, full of rapid swirls and eddies, though far above the entrance of these tunnels. It flowed rapidly through the culvert, and its outfall was a solid prism of water the full size of the tunnel projecting far into the river.

"The operation of this vast machinery was highly satisfactory. I went on several occasions down in the valve pits on the ladder of the casing, and to all accessible parts while in motion at its highest speed, and there was no undue vibration, only a uniform murmur of well-balanced parts, and the peculiar clash of the water against the sides of the casing as its velocity was checked by the blank spaces in the runner.

"This clashing of the water affords a means of detecting any faulty or unequal discharges from any of the openings of the runner. While moving at a uniform speed, this clashing has a tone whose pitch corresponds with that velocity of discharge, and if this tone is lacking in quality, or at all confused, there is want of equality of discharge through the various openings of the runner.

"To this part I gave close attention, and there was nothing that the ear could detect to indicate aught but the nicest adjustment. The bearings of the runners worked with great smoothness and did not become at all heated. Through a simple, novel arrangement, these bearings are lubricated and kept cool. There is a constant circulation of water from the pumps, by means of a small pipe which completes a circuit to an annular in the bearings back to the discharge pipe while the pump is in motion, requiring no oil and making it seemingly impossible to heat these bearings.

"The large cast-steel check valves placed in the *embouchement* of the pump casing, it was thought might act to check the free discharge, and arrangements were provided for raising and keeping them open by a long lever key attached to their axes of revolution; but, to our great surprise, at the first gush from the pumps, these valves, weighing nearly 1,500 pounds, were lifted into their recessed chambers giving an unobstructed opening to the flow, and they floated on its surface unsupported save by the swiftly-flowing water, without a movement, while the pump was in operation.

"The steam-actuated valves in the suction and discharge pipes worked very well, and the water cushion gave a slow uniform motion and without shock either in opening or closing them.

"The engines worked noiselessly without shock or labor. At no time during the trial was the throttle valve open more than three-eighths of an inch.

"The indicator cards taken at various intervals gave 796 horse-power and the revolutions did not exceed 160 at any time, though it was estimated that 900 horse-power and 210 revolutions would be necessary to attain the requisite delivery; so that there is a large reserve of power available at any time.

"The erection of this massive machinery has been admirably done, the parts, as sent from the shops of the contractor, have matched in all cases without interference and, when lowered into place, its final adjustment was then made without the use of chisel or file, and has never been touched since.

"The joints of steam and water connection were perfect, and the method of concentrating all valves, waste drips and important movements at the post of the engineer in charge gives him complete control of the whole system of each engine and pump without leaving his place, and reduces to a minimum the necessary attendance. All the parts are strong and of excellent design and workmanship, simple and without ornamentation. Looking down upon them from a level of the pump-house gallery, they are impressive and massive in their simplicity.

"The Government is well worthy of congratulation in possessing the largest pumping machinery of this type and of the greatest capacity in the world, and the contractors have reason to be proud of their work.

"There is nothing that a thorough trial has found wanting or that a careful retrospection suggests. It is ready for the purposes intended at any moment, so far as pertains to this department, and it is with a feeling of profound gratitude that I am enabled to make this announcement to the Bureau.

"Prior to the trial of the pumps, a simple, though delicate registering apparatus, was erected in the pump house, indicating on a large dial the number of feet and inches of the water in the dock above the suction tunnels. This furnishes most accurate information to the engineer of the quantity of water in the dock and the performances of the pumps, and warns him of the time for stopping the large pumps without incurring any of the risks involved in pumping too low and getting air into the pump casing.

"It worked most admirably during the trial, and was a check on the data taken at other points.

"In addition to the two forty-two-inch pumps for emptying the greatest bulk of water from the dock, an eight-inch centrifugal pump was furnished by the contractors for completing the discharge and for continuously removing the water of infiltration, which, though small in quantity, must be removed in order that its accumulation may not cover the floor of the dock and interfere with the operations of the workman.

" In order to test this pump the large gates in the drainage tunnels, near the invert, were closed down, leaving these tunnels full of water, and the water in the well at a level of the water in the dock. This gave a fixed and known quantity to be removed, and sufficiently large to afford a fair run of the pump. This was pumped out on two occasions, each of which gave a record beyond the requirements of the contract.

" The working of the engine and pump was all that could be desired, the steam pressure being fifty-five pounds per square inch, and the revolutions 350 per minute, the horsepower developed, as taken from the indicator diagrams, was thirty-two.

"The pump was charged with certainty and rapidity by means of the ejector at various levels of the water. This pump has been frequently used since its erection, and previous to the trial in removing the seepage water from the dock and has always worked admirably."

The board appointed for testing these pumps consisted of Captain F. V. McNair, U.S.N.; Chief Engineer George F. Kutz, U.S.N.; Civil Engineer C. C. Wolcott, U.S.N.; who conclude their report as follows :

" In making these tests, such conditions were imposed as would obtain in the usual operation of docking vessels; that is, the height of water in the dock was what it would contain were it occupied by an ordinary vessel, and with the state of the tide which would be chosen for beginning to discharge the water, giving a minimum of quantity to be removed. This, at the same time gave a somewhat severer test in obtaining the requisite average of discharge, for with the water in the dock at higher levels, the quantity discharged in the first few minutes would be very large, bringing the average for the whole to a much higher figure.

" During the trial, careful inspection of the machinery showed freedom from unusual vibration, and smoothness in action, as the result of well-proportioned and well-balanced parts, and with uniform velocity in revolution indicated equal discharge from all the openings in the runner.

" Tests were also made with all the pumps as to the ability of their steam ejectors to recharge them, and to continue pumping in case of stoppage, or their losing the water at any point, when the level of the water was below the centre of the runner.

"The trial was had in the case of the main pump with the water in the suction tunnel on a level with the fifth altar of the dock; with the small drainage pump it was recharged when the water had entirely left the floor of the dock, and was not more than two feet above the floor of the well.

"Finally, the board have to report that, the obligation of the contract in the mean capacity of discharge per minute of each of the main pumps and of the drainage pump, after a fair and thorough test, has been fulfilled, and that the general efficiency of each and all of these pumps is highly satisfactory."

4724 SPRINGFIELD AVENUE, PHILADELPHIA, PA., SEPTEMBER, 1894.

ELECTRICITY IN THE MODERN CITY.*

BY THOMAS COMMERFORD MARTIN.

[*Concluded from p. 211.*]

If you are not familiar with the statistics of electric railway work, I may commend them to your observation as another striking instance of the manner in which, in America. the visionary schemes of the inventor soon become the solid realization of the public. They show, I think, that in this respect, as in so many others, electricity is worthy of the graceful compliment that Florizel paid to Perdita: "What you do, still betters what is done."

For the vast majority of our cities and towns, electricity becomes the sole means by which they can enjoy that which counts for so much in the sum of comfort and convenience —swift, cheap, frequent and profitable transportation. Moreover, as Captain Eugene Griffin once put it: "The public was realizing that a good street railway security is better than a Western railway bond or stock. Electric railways will pay where no one would dream of building a horse road, and when the public taste is whetted for electrical securities we shall see a marvellous increase in the number of roads." That saying has already come to pass, and to-day, where you will find one new horse road or cable road projected, you will find at least 100 electric. That is near the actual proportion, with such results that the *Philadelphia Stockholder*, in a recent issue, published a diagram showing graphically that the dividends on all the street railways of the country are three times as large as those on the steam railways. It need not be wondered at, therefore, that local capital, which has hitherto been the mainstay of street railway enterprises, will have to compete with the investors of our centers of finance.

But I am not so much concerned with that, for a question of greater interest is that as to the effect of this change on the husbanding of other resources—I mean the vital, physical, moral and social elements of our city life. I look upon electric roads as a beneficial agency in the more uniform distribution of a happier population around any center, thus increasing the value of outlying property, and, by the stimulation of local trade, enhancing the profit earned in the area lying within the region thereafter more legitimately restricted to business occupancy. If a man is compelled to live in a city and pay high rent because rapid transit facilities are bad, he takes Irish views on the landlord question. If he lives far out and wastes his time and strength on a tiresome journey, he is an active sympathizer with the eight-hour movement. We all know that the value of real estate is affected by the concentration of population, and this is true of both office and dwelling property. But it is a singular fact that the discontent as to high rents does not apply to the occupancy of offices, and I think that one of the reasons of that has been that the majority of the workers in offices are either able to dwell nearer the scene of their labors, or, if living further out, are less restricted as to regular hours of service. But for the great bulk of any community the matter of dwellings is a most serious one, touching the deepest problems of life and conduct. Mr. Carroll D. Wright, the United States

Commissioner of Labor, put the case in a nutshell in a recent *Popular Science Monthly*, when he said: "By the old methods of transit from suburbs to the heart of the city, a workingman going into the city of Boston was practically obliged, while working ten hours at his occupation, to spend an hour on the horse railway, where now, by the use of the electric car, he can go and return from his place of work in half that time, thereby actually adding to his own time half an hour each day, practically reducing his working time from eleven hours to ten and a half hours, without reduction of wages and without increased expenses for transportation. The question of rapid transit, therefore, as seen by this simple illustration, becomes an ethical consideration; for if there is anything to be gained by adding to the time which men have at their disposal for their own purposes, for intercourse with their families, for social improvement, for everything for which leisure is supposed to be used, then the question of rapid transit is of far greater importance than that of saving money, either to the man who uses the transportation or to the company that secures dividends upon its stock."

To make such toiling men owners of their little homes seems to me infinitely more important than making them stalwart Republicans or Jefferson Democrats, and I would ten times rather see them sitting quietly and free in the shade of their rural fig trees than parading through the city mud and waving the banner of a ward boss, whose prosperity depends on their being under his thumb or heel, while they live in garret or cellar. No modern city anywhere has anything like adequate means of travel; and yet, when the time comes for a great city to exert itself, how the facilities of rapid transit make for a pure city government! Old London is herself an instance of this, for so long as her swarms hived within narrow limits she was municipally as corrupt as any city could well be; but to-day, with her population spread over a vast suburban area, and with multiplied means of communication, she governs herself as I believe no other community in the world can claim to do.

I am fully satisfied that much of the modern lack of individual interest in city life on its municipal side has arisen from these two things--the crowding together of the poor, and the living in remote suburbs of another part of the population, which, when it gets home, is too tired to come back even to resent public robbery and jobbery. But the evil has been a deeper one than this. Throughout this great country of ours there are about 11,500,000 dwellings, with nearly one family to each, that family being just a fraction short of five persons. But in New York City we have only 81,828 dwellings with an average of nearly four families per dwelling. As a matter of fact, only about twelve per cent. of all the families in New York have homes to themselves, and eighty-two per cent. live in tenements. Does anyone doubt that with more homes--or better rapid transit, which means the same thing—New York would be a better city? Does anyone doubt that if in better touch with her outlying suburbs, full of houseowners, Philadelphia would have a higher type of popular government than it now enjoys?

That electric roads do stimulate and vivify city life, is apparent to all who study the subject. We find at once that levelling up of values and that distribution of prosperity which is the aim and sum of all political economy. It is not at all an infrequent thing to see the adoption of electricity doubling and trebling the traffic of a street railway, while a permanent addition of thirty per cent. to the traffic is now taken as an absolutely safe minimum. It is unnecessary to point out what that means. Cambridge, Mass., with a population of about 70,000, pays the West End Company, of Boston, 50,000 to 60,000 fares daily, corresponding to five-sixths of the population on a single fare basis, and giving a total average of nearly 250 trips per year per inhabitant, or five times the general average for twenty-two other Massachusetts communities. As to the increased value of property, we may take the case of Brookline, Mass., where, owing to the service of the West End road, running at a suburban speed of twelve or fifteen miles an hour, the real estate valuation has risen far above $30,000,000 from about $17,000,000 in 1885. Every member of the community is the richer for that change, and the same assertion might be made for scores and scores of other communities. The little electric road, that has cost, perhaps, $100,000, has added ten times that value to the property; it has brought the price of land within the means of the people, to whom the ownership of house and home, even in this boundless America of ours, began to be as improbable as the possession of an Atlantic steamship.

Moreover, look at many of the additional uses to which these electric roads are being put. In some cities they carry the mails regularly. In others, their extension of the express system has given an entirely new development to the freight business. In many cities there are funeral cars that simplify and cheapen the heavy burdens of decent burial. Several roads have been built as links between steam roads, while others give the people access in the summer time to breathing spaces that were previously beyond reach. I have even heard of hotels whose peculiar feature of excellence is, that they have electric cars running to and from the depots for the particular benefit of their patrons.

It may be said that I am very much alive to the advantages of electric traction and not a little blind to their defects. Perhaps that is true, but it has seemed to me that the assailants of electricity did not need any help. I am not talking about a perfect thing. Few of our electrical applications have seen their best days. I am free to confess, however, that it does disgust me to hear people complaining about the ugliness of the overhead wires or the dangers of the trolley, while they complacently tolerate evils that really have an existence. I echo the remark of Mr. Frederic Harrison, that "To decry steam and electricity, inventions and products, is hardly more foolish than to deny the price which civilization itself has to pay for the use of them." When I hear people in New York abusing overhead wires and almost in the same breath advocating an extension of the elevated railway system, I pray God to spare me from any such obliquity of vision.

Not long ago, a fellow-citizen of mine, who was railing against overhead wires along a certain street, was unable to say on which side of the street the wires were. Now, I will take second place to no man in civic pride or in admiration of fine thoroughfares, but I fail utterly to see that a good piece of overhead trolley construction is inferior in comeliness to the architecture of most of the streets it occupies. On the contrary, I have seen many a street, whose whole air of thrift, and whose only pretence to trimness and symmetry, was due to the wires that ran above it. Another point is the accusation of danger brought against electric cars. Now, as a matter of fact, electric cars in this country have already carried more passengers than would equal the entire population of the globe, and I defy anyone to point to a single instance in which a passenger has been killed or even injured by the current. Other accidents you will have, of course. Electric and cable cars travel faster than horse cars, and hence, there is, upon their introduction, an increased number of accidents from the unfamiliarity of pedestrians and drivers with their speed. But, even if this higher number should be maintained, I must insist that against it shall be put the saving of life and the increase of health that come from the adoption of a method which gives back to the dweller in the city his birthright in the country.

One more point, and I will refrain from the discussion of a topic that has so many aspects. It is commonly and truly understood that the resort to electricity, while accompanied generally by large investment, leads to a saving in operating expenses. For example, the Rochester Street Railway, for June, 1891, showed earnings with electric cars 22·77 cents per mile, and expenses 11·07 cents; while their cars with horses earned 14·37 cents and cost 12·06 cents to run. In other words, the net earnings with electricity were 11·70 cents, and with horses 3·31 cents. The assumption generally is that the city granting the franchise should share directly from this saving, as well as indirectly from the increment in the taxable value of property, and from taxation of the road in the ordinary way. In many respects the theory is right, but as our old friend, Captain Cuttle, would say: "The bearings of this observation lies in the application of it."

This very desire to exact a share in the benefits of a new thing, so beset and burdened the electric light in England, that, even to-day, though now encouraged by less grasping legislation, it is still scarcely known. In New York our experience in putting up street railway franchises to the highest bidder has taught a painful lesson in the repression of new enterprises that are badly needed.

The question very often resolves itself into the balancing of advantages. It may, on the one hand, be well to get a few thousand dollars in extra taxes; but if this exaction, well meant though it be, compels the company to use old and inferior rolling stock, or to curtail the service on lines it would like to build up, then the city would be richer in the long run if its citizens could ride about in new cars and did not have to linger about street corners on bleak nights waiting for the car that seems as though it would never come. There is open the alternative of city ownership, a plan which appears feasible only when the city owns the road and leases it. This practice obtains in Glasgow and Liverpool, and, as might have been expected, the double responsibility leads to no end of trouble. Our American cities may, perhaps, be in shape to try the experiment, after they have learned how to keep their existing highways in decent condition.

I hope soon to see overhead trolley cars supplemented by storage battery cars, and by conduit trolley cars, and, more particularly in large cities, by elevated and underground electric roads. Evidently it is only with tracks above or below the surface that we can ever attain the high speed to which the phrase "rapid transit" will justly apply; and I think that by-and-by, in our largest cities, travel will be wholly by electricity, above or below the street surface. It is for that reason, but in no other sense, that I regard the trolley system as a make-shift. On the contrary, it is worthy the praise and support of every American proud of American inventive genius, and of the quick American apprecia tion of new methods and ideas.

There remain many branches of electrical work that I have not touched upon, which are really of vast importance to the dweller in the modern city, but I have devoted the hour to the leading three—the communication of news and intelligence, the use of electricity for light, heat and power, and the employment of the electric motor as a means of traction—thus affecting the three greatest elements in our daily city life.

AËRIAL NAVIGATION.

By. A. F. Zahm, Johns Hopkins University.*

In his lecture on aërial navigation delivered before the students of Cornell University in 1890, Mr. Chanute began his remarks with a hesitancy amounting almost to reluctance, seeming to entreat the young men not to believe that the study of such a subject was a more than probable indication of failing mental vigor. If he could appear before you this evening it would doubtless be very gratifying to him to realize that an audience of sober scientists and engineers were willing to listen for an hour to hear something of the venturesome art of flying through the air.

It is indeed a source of pleasure to all earnest students of aërial navigation to observe the general awakening of public interest in their efforts within recent years; for it lends, as it were, a dignity and reasonableness to their pursuits which is at all times comforting. It almost inspires them with the courage to experiment in the broad light of day, to forsake the garret and the lone watches of the moon, to come out from behind the hedge rows and to look the inquiring world frankly in the face. Let us hope that their achievements may justify the public attention and that the present sympathy of engineers may but prove one of the earlier manifestations of

"The prophetic soul
Of the wide world dreaming on things to come."

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*A lecture delivered before the Franklin Institute, January 5, 1894.

Just at present the public seems, if possible, even more confident of the possibilities of aërial navigation than the investigators themselves. It seems quite prepared to abandon the boat and the railway car, with all the pleasures of land and of sea, for the winged chariot and the untrammeled vast above us; quite ready to realize the visions of Darwin and of Tennyson, even to the extent of seeing "the heavens fill with commerce" and of witnessing "the nations airy navies grappling in the central blue." The experimenters, however, would be more than contented if they could but guide their adventurous way and hold an even course through the treacherous depths of the atmosphere, leaving to other times the more ambitious adaptations and the fuller enjoyment of their labors.

I think we may profitably notice four classes of aërial navigators who have accomplished some good work and who promise further achievements of value. We may notice (1) the "*passive balloonists*," or those who employ no motive power and make no endeavor to control their course through the air more than may be effected by choosing favorable currents; (2) the "*active balloonists*," or those who employ the utmost attainable motive power in their endeavor to cope with the prevailing winds, and to pursue their course at will in any direction; (3) the "*active aviators*," or those who would fly through the air in massive unbuoyant machines actuated by wings or screws, and dependent both for support and propulsion upon the energy of extremely light and powerful motors; (4) the "*passive aviators*," or those who are trying to soar on outstretched wings depending for support and propulsion entirely upon the energy of the wind.

PASSIVE AËRONAUTICS.

Though it has long been a dream with the passive or free balloonists that they may discover in the upper atmosphere extensive trade-winds in which they may sail with security and precision over vast distances, the most valuable outcome of their explorations thus far has been the recording of phenomena observed in the regions of the clouds.

These phenomena have proved of immense interest to meteorologists, and are likely to receive considerable attention in the immediate future. Propositions for further exploration of the upper air are being discussed in the meteorological journals and societies which would indicate that this is one of the most serious problems calling for immediate solution. It will certainly prove a magnificent achievement both for meteorology and aëronautics if the great trade-winds of the upper atmosphere can be plotted as definitely as the currents of the ocean.

It has long been a conviction with aëronauts that such currents exist, and that they are well worth serious study. Mr. Wise, the pioneer of aëronautics in this country, was so confident of a steady west wind a few thousand feet above us, that he thought it could be employed for regular voyages across the continent, if not across the ocean. Mr. Hazen, of the Weather Bureau, is no less enthusiastic about the existence and importance of such winds. In answer to my inquiries on this subject, he replies: "There is no question that the currents above about 6,000 feet have a pretty steady motion from the west. On Mt. Washington, N. H., at a height of 6,300 feet, the winds are constantly from the west. It is safe to say that the irregular or circulatory winds of our storms very nearly disappear at a height of about 4,000 feet, and from that height to 6,000 feet the current becomes more and more steady from the west. Here, in Washington, I have never seen a true cirrus moving from the east (N. E. to S. E.). These clouds range from 10,000 to 20,000 feet in elevation, though at times they reach 20,000 to 25,000 feet. At Mt. Washington, a good number of instances have been recorded of winds blowing eighty to ninety miles an hour and lasting twenty-four hours or more. It is now pretty well known when we may expect such winds, and there ought not to be the slightest difficulty in making the voyage from Denver to New York, and after that from New York to England."

While on this point, I may mention a most interesting paper on the exploration of the upper atmosphere, contributed to the Chicago Conference on Aërial Navigation, by M.

DeFonvielle, of Paris, in which he describes some records obtained by M. Heremite at extraordinary altitudes. It had formerly been proposed to employ closed and heated cars to protect aëronauts from asphyxia and freezing at elevations above six or seven miles, but the expense of constructing a balloon so equipped had prevented such enterprise. M. Heremite accordingly determined, in 1892, to construct very light balloons of goldbeater's skin, and of sufficient capacity to carry up self-recording instruments, believing that the balloons might float for some hours at random, and, on falling to earth, be discovered by someone who could telegraph to him at Paris, according to printed instructions sent with the balloon. In this he was not disappointed; for it was found that in a well populated and civilized country like France, a large percentage of the balloons could be recovered with their instruments in good order.

On the 21st of March, 1893, such a balloon, measuring about twenty feet in diameter, was liberated at mid-day, and rose with great rapidity to an altitude far exceeding any height ever attained by an aëronaut, where it floated till late in the afternoon, descending to the earth about seven o'clock in the evening. It was recovered the next morning, and when the records were examined, it was found that the balloon had risen from the earth with a velocity of nearly twenty miles an hour, having ascended 8,530 feet in five minutes after its departure. In twenty minutes it had attained an elevation of eight miles, and shortly afterward soared up to its maximum height of 52,494 feet, or very nearly ten miles, which far surpassed anything of the kind hitherto achieved. The temperature steadily fell as the balloon arose until the barometer indicated an elevation of 45,920 feet, whereupon the ink in the recording thermometer froze. M. Heremite estimates that at the maximum altitude attained by the balloon, the temperature of the surrounding air was 256° below zero, Fahrenheit, thus indicating that the temperature of the atmosphere fell on an average 1° for each 165 feet of ascent above the earth's surface. He further estimates that the temperature of absolute zero,—459°·40 F., will be reached at a height of 85,303 feet, or a little over sixteen miles, and that this altitude may perhaps be attained by his exploring balloons.

These facts, however, interesting and valuable they may be in their relations to the other sciences, do not so directly concern us here as the records of the velocity and direction of the wind. M. DeFonvielle informs us that the paths of the balloons which rose to a great elevation above Paris indicated a general eastward direction for the currents in which they sailed and that their velocity did not appear to be very great. This latter observation is in striking contrast to the extraordinary figures given by some observers in America who assure us that the velocity of the upper clouds as determined by triangulation, is quite usually between 75 and 100 miles per hour.

It is understood that the experiments above described are still continuing in France and it is hoped that similar ones may be attempted in other civilized countries, for whether or not they result in furnishing us with a chart of the atmosphere they will doubtless throw light upon a multitude of problems. The extraordinary results set forth in DeFonvielle's paper have not been satisfactorily verified as yet, but I have thought proper to mention them because the investigations are still in progress and are calling forth no little comment.

ACTIVE AËRONAUTICS.

As it is manifest that no probable combination of differently blowing winds in the upper atmosphere could completely serve the demands of a perfect system of aëronautics, inventors have from the beginning made strenuous efforts to guide and propel their vessels independently of the weather. A vast number and variety of schemes have been proposed, most of them evincing a paltry knowledge of mechanics or of anything else; for it has ever been a grand passion, an alluring dream, with the imaginative inventors, to sail at will amid the pomps and glory of the clouds. Yet, however laborious and earnest their efforts may have been, the service they have rendered mankind must be regarded as of a negative kind. The second rate inventor can usually be of some service in the advancement of mechanics by suggesting improvements of detail; but when he dares to create a complete air-ship alone, the burden of it is sure to wreck his mind and empty his purse.

The problem of navigating the air has proved to be a most formidable one; for it presents nearly all the difficulties of submarine navigation with few of its facilities. The fickle element can offer but one-eighth of one per cent. of the support of water; it is forever changing its density with sunshine and shadow, and a multitude of causes; it sweeps along quite usually with torrential velocities; it is vexed with whirls, and undulations, and breakers for the most part invisible to the eye. It offers, indeed, a proportionately small resistance to progression; it exhibits an almost negligible viscoscity; but the frail structures which weather it must possess enormous dimensions and carry huge propellers actuated by despairingly light and powerful motors. Finally to the host of other difficulties must be added the financial one; for small vessels are of small scientific value, and large ones bankrupt the experimenter without bringing return.

Yet in spite of these odds, men of excellent judgment have dared to stem the currents of this nimble sea, and have already won a measure of success. The labors of the indefatigable Frenchmen, of Meusnier, of Giffard, of Dupuy de Lôme, of the Tissandier brothers, and finally of Renard and Krebs, have steadily advanced the construction and capacity of the dirigible balloon till it may almost be said to vie with its maritime neighbor in grace and speed. Giffard's balloon, which was constructed in 1852, and was propelled by a steam engine actuating a screw, is reported to have sailed with a speed of four and a half to six and a half miles an hour, or about the same as that of the first steamboat. Dupuy de Lome, ten years later, greatly improved the construction of the balloon, but, unfortunately, employed men instead of a steam motor to operate the driving screw. Still he attained a speed of over six miles an hour. Eleven years later the Tissandier brothers, employing a similar balloon driven by electric motive power, obtained a speed of 6·7 miles an hour, and two years later raised this record to 8·9 miles an hour. In the meantime the French government had been preparing a balloon which for the beauty of its outline, the strength of its construction and the perfection of its propelling apparatus, should excel everything thus far attempted. When finally launched August 9, 1884, it immediately rose in the air and began its memorable voyage from Chalais at a speed of nearly eleven miles an hour.

It may be well to give a fuller description of the construction and performance of this famous balloon, called La France, whose successful manoeuvres created so much enthusiasm and excited so much speculation in the past decade. In outline it looks not unlike a great cigar placed horizontally in the air. It measures 165 feet in length, 27·5 feet in its greatest diameter, which is one-fourth of the distance from the front end, and possesses a buoyancy of 4,400 pounds. Beneath the balloon proper a long, narrow car, made of bamboo and covered with silk, is suspended from the cords of the netting which embraces the balloon throughout nearly its entire length. The car is 108 feet long and 6 to 7 feet across, carries at its forward end the propeller, at its rear, the rudder, and between them, the aëronauts and the batteries and electric motor which supply the propelling power. The length of this balloon is six times its diameter, which is a much greater proportion than had been exhibited by any of the successful vessels which had preceded it. Its centre of traction is also placed relatively much nearer the centre of resistance, and the sustaining cords are disposed so as to offer slight resistance to progression, while at the same time affording rigidity and permanence of shape

The electric motor and battery which furnish the propulsive power of this balloon, were designed expressly for such use, and were considered at the time to be remarkably light and powerful. The motor, which was designed with the assistance of M. Gramme, weighed 220·5 pounds, and developed nine horse-power. The battery was the result of the researches of Renard himself. "The great total energy of this battery," Mr. Soreau tells us, "is due principally to the substitution of chromic acid for the bichromate, whose alkaline base absorbs, in reaction, a portion of the exciting liquid. Its capacity reaches its maximum when the weight of the chromic acid is equal to five-sixths that of the hydrogen acids. Then fifty-five watts per square decimeter per hour is obtained. The rate of current is obtained by the partial or total substitution of hydrochloric acid for sulphuric acid in the bichromate batteries; the total energy of the mixture does not change, but the energy per second increases with hydrochloric acid, and can be quintupled."

Having made a careful study of the best geometrical arrangement of the parts of the cell Renard found that this battery would deliver to the shaft one horse-power for each eighty-eight pounds of its weight.

It may be interesting to compare the capacities of the various motors thus far employed for aëronautical purposes. Giffard's steam engine and boiler taken together, without fuel or water, weighed, according to his own report of September, 1852, 110 pounds per horse-power. The electric motor used by the Tissandier Brothers, which derived its current from a bichromate of soda battery, weighed, together with the battery and sufficient liquid for two-and-a-half hours' work, a little more than 330·6 pounds per horse-power.

The electric motor and battery used by Renard weighed, as shown by the data given above, about 112·7 pounds per horse-power; or 130 pounds per horse-power, if equipped to run one and one-half hours.

As we shall see later, these motors are immensely heavier than the steam engines recently constructed for purposes of mechanical flight; but it is understood that electric motors have also been very much reduced in weight since the experiments with La France, in 1884–85. M. Trouvé is said to have constructed an electric motor wound with aluminum wire instead of copper, which weighs but 7·7 pounds per horse-power without the battery. Mr. Soreau informs us, in his excellent memoir read last February before the French Society of Civil Engineers, that the researches of Renard have led to the invention of an electric motor and battery weighing one-and-one-half times less than the one used in La France, and this with supplies enough to last for twelve hours.

The ascensions of La France in 1884–85, if we regard them as experiments, ought to be considered as extremely successful and encouraging; not that they represented or pointed to the complete achievement of aërial navigation, but because they so far surpassed all previous successes. The balloon moved through the air as steadily as a boat upon the water, and obeyed her rudder perfectly, heading against the wind or at any angle to it, or turning entirely about at the will of the aeronauts. On her first voyage from Chalais she traversed a distance of four-and-one-half miles in twenty minutes, made various evolutions in the air with the greatest ease, and returned to her point of departure. The following account of this voyage is given by Renard: "As soon as we had reached the top of the wooded plateaus which surrounded the valleys of Chalais, we started the screw, and had the satisfaction of seeing the balloon immediately obey it and readily follow every turn of the rudder. We felt that we were absolutely masters of our own movements, and that we could traverse the atmosphere in any direction as easily as a steam launch could make its evolutions on a calm lake. After having accomplished our purpose, we turned our head toward the point of departure and we soon saw it approaching us. The walls of the park of Chalais were passed anew, and our landing appeared at our feet about 1,000 feet below the car. The screw was then slowed down and a pull at the safety-valve started the descent, during which, by means of the propeller and rudder, the balloon was maintained directly over the point where our assistants awaited us. Everything occurred according to our plan, and the car was soon resting quietly on the lawn where our assistants awaited us."

Six other similar voyages were made within the two years following, and we have as a result, that in five out of the seven trials, the balloon returned to its point of departure. Its failure to return in the other two trials was due, in the one case, to the breaking down of the motor: in the other, to the resistance of a strong wind which made it necessary to land at a distance from the starting point. The last of these remarkable voyages was performed in presence of the Minister of War, on the 23d of September, in 1885. The balloon started from Chalais and sailed against the wind directly to Paris, passed over the fortifications, described a graceful curve and returned to its place of departure, recording an average speed of 14·5 miles an hour.

After these ascensions so little was heard from the laboratory of Chalais that the public began to regard the brilliant voyages of 1884–85 as the final and ultimate possibility of aëronautics, and to believe that Renard's silence was due to a loss of confidence in the navigable war-balloon. He was, however, continuing his researches with great earnestness and with much secrecy, as they were considered to be of importance to the national defence. Finally, about a year ago, it was announced that he was preparing to experiment with a new war-balloon of extraordinary capacity, calculated to attain a speed of 24·8 miles an hour and to operate in the air twelve hours at a time. In exterior figure this balloon will resemble La France; it will measure 230 feet in length, 42½ feet in greatest diameter, and will be propelled by a screw about 30 feet in diameter. With this vessel it will, therefore, be possible to execute a journey of 300 miles between dawn and dark without the aid of the wind and without halting for supplies.

After this balloon has been tested others will doubtless follow in proportion to the efficiency manifested and the probable demand for such instruments of war.

We naturally inquire: What will be the ultimate speed and use of the navigable balloon? And this is, at present, an open question. There are enthusiasts who argue that speeds of forty to fifty miles an hour may be attained, and that, therefore, the air-ship may find a variety of commercial uses. I may mention that Giffard, after the success of his first experiments, prepared the plans of a mammoth vessel which was to be propelled at a speed of forty-four miles an hour, even with the engines he could then command. So confident was he indeed, that he obtained a patent for, and means to venture the expense of constructing a balloon nearly two thousand feet long—a work he would undoubtedly have attempted had not blindness overtaken and prevented him. Since his day a variety of similar proposals have been made. Some inventors have advocated constructing gigantic vessels of aluminum, or steel, upon the covering of which the propellers should be planted so as to exert their united pull in the line of resistance, and we should not be surprised if some daring engineer should one day attempt some such ambitious construction. On the other hand the more prudent engineers contend that speeds above thirty to thirty-five miles an hour are impossible, or, if physically possible, that the enormous power required, the frailness of the envelope, the cost of housing and repairs, and the scant carrying capacity, would render the air-ship forever impracticable for commercial purposes.

In this speculation it is interesting to observe that the navigable balloon does not fail for lack of strength to endure high velocities or surging storms, for it may be shown by very simple calculation that a large hull made of fabric, or metal, and inflated under pressure, may be made amply strong enough to withstand a velocity through the air of fifty to sixty miles an hour, if the propulsive force be well distributed. I desire especially to direct your attention to this fact, because some of the most eminent advocates of flying-machines have asserted that balloons could not be made strong enough to endure any considerable speed. It may be added also that it is physically possible with our present light motors to propel a large balloon at a speed of fifty to sixty miles an hour, though I would not for a moment assert that it is mechanically practicable.

To prepare the dirigible balloon to run at high velocities, it will be necessary to keep it continuously rigid, and to locate the propellers near the centre of resistance. The first of these requirements can be fulfilled by inflating it under pressure; the second, by planting the propellers directly on the covering of the vessel. This means that the envelope should be made of very stout and impervious material, perhaps of metal, and hence, that it should be of titanic proportions. Here, of course, lies the real difficulty; for, while it may be simple enough for a mathematician to indicate the most favorable dimensions for an air-ship of great strength and speed, the realization of his figures may present insuperable bounds to the financier, if not to the mechanician.

Leaving aside the question of finance, which is not usually urged as an objection, let us consider merely the physical possibility of such a construction. Selecting La France as a model, let us estimate the capacity of an air-ship of ten times her linear dimensions. The data we shall require are as follows: length of La France, 165 feet; greatest diameter, 27·5 feet; surface, 10,000 square feet; buoyancy, 4,400 pounds; speed, 12 miles an hour; resistance at 12 miles an hour, 50 pounds. Remembering that the buoyancy of a balloon increases as the cube of its linear extent, while the surface and resistance increase only as the square, we have for a balloon of ten times the linear measurement of La France and moving 12 miles an hour, the following: length, 1,650 feet; greatest diameter, 275 feet; surface, 1,000,000 square feet; buoyancy, 4,400,000 pounds; resistance, 5,000 pounds. The power required to overcome a resistance of 5,000 pounds, 12 miles an hour, allowing an efficiency of 50 per cent. for the screw-propeller, is 320 horse-power, which, if supplied by a motor of Mr. Maxim's design, would imply a weight of only 3,200 pounds. Suppose the motor to weigh 400,000 pounds, or 125 times the weight above found necessary; it will then be competent to propel the balloon sixty miles an hour, and still leave 4,000,000 pounds surplus buoyancy. We thus see that a motor fit to carry a flying-machine will also propel a balloon at a high rate of speed.

We have next to inquire whether the vessel can be made strong enough to support the enormous pressure of the air at this velocity. The resistance of a plane surface moving normally at the rate of sixty miles an hour, is, roughly, eighteen pounds per square foot; and if the internal pressure of the gas can be safely raised to this amount, it is clear that the balloon may be driven a mile a minute without collapsing. Let us allow 2,000,000 pounds for the covering of the balloon. If we construct it of uniform sheet steel, the metal will be ·05 of an inch thick and subject to a tensile stress of 4,125 pounds, when the covering is inflated under a pressure of eighteen pounds per square foot. Hence, a steel balloon may easily endure a speed of sixty miles an hour, without danger of collapsing, if it be properly propelled.

A balloon of such strength and inflation would require no net, and both cargo and motors could be supported directly upon the covering. The two million pounds remaining for passengers, cargo and supplies would occupy relatively such small room that the general exterior of the vessel would appear plump and smooth as a whale. There being then no boat, netting or other projecting parts to oppose the progress of the vessel, save the numerous small propellers putting out from its surface, it should move with a relatively less resistence than La France. It would appear from these figures that a balloon competent to carry many hundreds of passengers at speeds rivalling those of the railway train is among the physical possibilities if not commercially practicable. It would afford an interesting exercise to an inventor to work out the details of constructing, housing and repairing such a vessel, of controlling its movements when in use, of inflating it and of preserving its barometric equilibrium. It may be observed that at a speed of thirty miles an hour the power required would be one-eighth as much, and the strain of the vessel one-fourth as much, as at a speed of sixty miles an hour.

ACTIVE AVIATION.

There has naturally been much speculation as to whether we should navigate the heavens in air-ships or flying-machines. From the day of the launching of the first crude Montgolfier there have existed two rival schools of enthusiasts, who, with more acrimony than love, have waged a prophetic contention over the future empire of the illimitable sky. The aëronauts boast of having at least fairly launched themselves while the aviators have not been able to quit the earth. The aviators in turn point to the birds which move with such celerity and ease, while the great gas-bags drift helpless in the currents of the atmosphere. Perhaps ere long it will be discovered that there is room in the sky for both; for certainly each school has plausibly met the objections urged against its propositions.

For a century the odds seemed to be unquestionably all on one side. For just a century, the aëronauts, buoyed up by a subtler element and the hope that springs from partial success, paraded their enormous bags in every land, while the aviators stood pluming their incompetent wings and pointing to the birds as an apology for their own existence. But the century ended ten years ago, and within the past decade the aviators have so far prospered as to dare call themselves even more than rivals on the airy deep.

The remarkable advances of the science of aviation within the past decade, and especially within the past five years, may be chiefly attributed to two great discoveries: (1) That the power required for direct mechanical flight is far less than was formerly estimated; (2) that this power can actually be more than obtained from well designed steam engines.

As to the estimate proposed by various writers for the power exerted in bird-flight, Mr. Maxim gives us the following quaint summary: "Many years ago a mathematician in France wrote a treatise in which he proved that the common goose in flying exerted a force equal to 200 horse-power; another proved that it was only fifty horse-power, and he was followed by still another who proved very much to his own satisfaction that it was only ten horse-power. Later on, another wrote to prove that a goose expends only about one horse-power in flying. At the present time, however, many mathematicians may be found who are ready to prove that only one-tenth part of a horse-power is expended by a goose."

This is evidently an advancement of 200,000 per cent. in favor of human flight. Mr. Maxim, reasoning from the data of his own carefully conducted experiments, would reduce even this last figure. "The goose would," says he, "exert no more than ·083 of a horse-power, which is rather more than a man power, and is at the rate of 144·5 pounds per horse-power."

At the International Congress of Aëronauts and Aviators, held at Paris, in 1889, two papers were read, one by Mr. Drzewieki, a Russian engineer, and the other by Mr. Chanute, of Chicago, which presented some new and more encouraging views of the requirements of flight than had formerly prevailed. Mr. Drzewieki, insisting that the bird's wing during rapid flight performs the role of both a screw and an aëroplane—that is to say, that the outer quill feathers pull the bird forward, while those near the body sustain it by their continuous gliding action—estimated, by the aid of empirical formulæ, the various resistances to forward progression encountered by the bird and the powers expended in overcoming them at various velocities and angles of flight. As a result, he concluded that the most favorable angle of flight, or that of minimum resistance, is 1° 50′ 45″, an estimate which agreed very closely with that obtained by Mr. Chanute from a theoretical analysis. Mr. Drzewieki then calculated the power needed to drive an aëroplane at this angle, assuming that its cross-section, which would offer a hull resistance, should measure one per cent. of its horizontal projection. He gave, as his conclusion, that to carry a burden of one ton including its own weight through the air at a speed of twenty-five miles an hour, would require 5·87 horse-power.

Mr. Chanute's investigation of the power expended by the common pigeon flying at this velocity and with its much greater proportion of hull resistance, lead him to believe that an equally efficient large machine would need 10·49 horse-power to carry one ton at a speed of twenty-five miles an hour.

These were encouraging figures, surely, and they seemed to be well corroborated by the systematic investigations of both Mr. Maxim, of England, and Dr. Langley, of the Smithsonian Institution. After a long series of delicate measurements of the carrying capacity of inclined planes gliding on the air at various angles and velocities, Langley informs us that one horse-power, properly applied to the propulsion of an aëroplane, may sustain fully 200 pounds and upwards. Maxim, who experimented with much larger planes, concludes that certainly as much as 133 pounds may be sustained by the expenditure of one horse-power (13·53 horse-power per ton), and under certain conditions as much as 250 pounds.

These conclusions refer only to simple plane surfaces, and it is desirable to learn what corrections to make for an actual flying machine offering a hull resistance. We fortunately have some data furnished by practical trials. Mr. Tatin, of France, informs us that his aëroplane sustained 110 pounds per horse-power; Mr. Phillips, of England, records 72 pounds; and Mr. Hargrave, of Australia, as much as 89 pounds per horse-power. Mr. Chanute, in concluding his exhaustive articles in the *American Engineer*, expresses his belief that 45 pounds per horse-power may be supported in practice by the direct action of a screw, or 100 pounds per horse-power by means either of flapping wings, or by means of an aëroplane urged by a screw. He has also inquired what proportion of the entire weight sustained may be devoted to the motor in a machine large enough to carry one man. He presents us his conclusions in the following interesting table:

Kind of Apparatus.	Pounds Sustained per H. P.	Proportion Available for Motor.	Resulting Possible Weight of Motor per H. P.
Screws	45	⅓	15
Wings	100	¼	25
Aëroplanes	100	½	50

With these figures before us we may glance at the list of the various motors that have been employed for purposes of aërial navigation and see how nearly they have met these requirements. In the first rude essays at human flight the only available source of power was that of the human muscle, which meant at least a thousand pounds per horse-power, if continued for any length of time. Giffard's boiler and engine without supplies weighed, as we have seen, 110 pounds per horse-power, Tissandier's motor and battery 330·6 pounds, Renard's motor and battery, according to the most favorable and latest reports, 66 pounds. Evidently these were all too heavy. Mr. Stringfellow's famous little steam engine and boiler is reported to have exerted one horse-power and to have weighed, without supplies, only 13 pounds. If we allow 25 pounds an hour for fuel and water it would appear, from the above table, that such a motor ought to fly an hour and a half. Its performance, however, did not realize all that was expected of it. It may be remarked in passing that the lighter electric motors of Renard and Trouvé were amply powerful enough to operate a trolley flying machine. It might be suggested also that such a machine would offer the readiest and most economical means of studying the questions of stability and steering, for it would be cheap to construct, and in flying would behave very nearly like a machine in free flight.

Such was the prospect of aviation up to the period of the French Aëronautical Congress of 1889. Not only had men an exaggerated notion of the power required for flight, but they had also only a vague conception of the capabilities of artificial motors. Mr. Stringfellow's little model seemed to represent almost the ultimatum of steam-engines, yet it had not flown successfully. It was declared that artificial motors would have to be made to rival the birds in relative output, an attainment which did not then seem feasible. Indeed, one philosopher, and a well-known American writer, published an article in which he demonstrated in the most eloquent and positive language that such an achievement was absolutely impossible. Nature had tried for centuries to produce a relatively lighter prime-mover than the bird and had failed; it was therefore senseless for man to hope ever to do so.

While scientific and unscientific writers were indulging in these speculations, Mr. Maxim went resolutely to work and at one step, reduced the weight of the steam engine, with its boiler and condenser, to less than ten pounds per horse-power; and now that he has so completely outstripped nature, who will again look to her as sole mistress? To add to the chagrin of such speculations, Mr. Maxim expresses the belief that a useful working boiler and steam-engine can be constructed to weight but five pounds per horse-power. "I am of the opinion," he writes, "that with a generator and engine especially constructed for lightness, a naphtha motor could be constructed which would develop one hundred actual horse-power and not weigh more than five hundred pounds, including the condenser, and still have a factor of safety quite as large as we find in locomotive practice." These announcements have certainly astonished the scientific and engineering world.

We have since been apprised of the labors of several other inventors which bid fair to rival even Mr. Maxim's achievements. Mr. Phillips of England, has an engine, whose actual power I have not learned, which, with its unique aëroplane, can readily lift itself from the ground and fly forward at a considerable speed. After observing the performances of this machine, Mr. Breary, Secretary of the British Aëronautical Society, wrote me last July that he thought we might "soon throw up our hats." Mr. Mosher, builder of the "Norwood," informed us last August, at the Conference on Aërial Navigation, that he was prepared to furnish specifications and build aëronautical engines for experimental purposes that should weigh no more than ten pounds per horse-power. Mr. Hargrave informed us, in a paper contributed to the same conference, that he had constructed an engine and boiler which, with twenty-one ounces of fuel and water, weighed but seven pounds and developed 0·653 of a horse-power, or at the rate of one horse-power for 10·7 pounds of total weight. He states that his present construction is cheap and simple and that he sees how it may be considerably reduced in weight. The copper tubing of his boiler, for example, which weighs thirty-seven ounces may be reduced to eight ounces and still be abundantly strong, while at the same time retaining its evaporative capacity.

It may be interesting here to make an observation regarding the design of aëronautical boilers. It can be proved that if one pound of copper be drawn into a long boiler tube, capable of resisting a given pressure, the solid contents of the tube will be the same, however small its diameter may be. It can be shown, also, that if two such tubes have equal weight, equal interior capacity and bursting strength, but unequal diameters, their convex surfaces, that is to say, their evaporative powers, will be inversely as the diameters of the tubes. From this it would appear that a boiler composed, for example, of quarter-inch tubes, would possess sixteen times as much heating surface and, consequently, sixteen times as much evaporative power, as a boiler of equal weight made of four-inch tubes. It may be added also, that the total space occupied by the tubes of each boiler, would be equal if the relative arrangement were the same; and that, as the diameter of the tubes became indefinitely small, the heating surface would become indefinitely great.

But this is a digression. When the power required for direct flight had been determined with some degree of accuracy, and the motors capable of supplying such power were an assured reality, the attention of engineers was especially directed by several writers to another remarkable fact, which, so far as I am aware, was first proved by A. Du Roy de Bruignac, and, in 1875, formally enunciated by him, in the following words: "Providing the angle of a heavy plane, moving in the air, be maintained at the minimum necessary to sustain its weight, the work of translation diminishes as the velocity increases." Mr. Chanute, in his recent book on aviation, p. 43, shows that this statement may also be applied to birds and flying-machines moving at limited speeds, say of thirty to forty miles an hour. He further shows, in his little pamphlet on Aërial Navigation, published by the *American Engineer*, that to carry a ton of weight through the air at these speeds on a flying-machine, would require very much less power than to carry the same in the best navigable balloon thus far designed.

These are surely formidable arguments in favor of mechanical flight, and it is not strange that they should excite hope. It is not surprising that the final decade of the century should witness extraordinary and perhaps final efforts to ride the air on expanded wings. When we remember that at the Aëronautical Conference of 1889 men were just beginning to see their way clearly, while at the Conference of 1893 they were discussing full-fledged machines of excellent promise, we may not unreasonably hope that at the Paris Conference of 1900 we may be offered printed excursion tickets for actual flights through the air. The attraction ought surely to equal that of a tower or of a great revolving wheel.

Since the beginning of the year 1890 a great number of elaborate experiments with flying-machines have been announced, some of which we may briefly notice here; the most promising of these being the experiments of Mr. Maxim and of Mr. Phillips in England and of Mr. Hargrave in Australia.

Mr Maxim's machine looks not unlike a locomotive rigidly suspended by small rods from a great kite which it drives forward by the aid of a pair of large horizontal screws. The following particulars of it are taken from Mr. Maxim's description in the *New York Sun* for May, 1890: "My large apparatus is provided with a plane 110 feet long and 40 feet wide, made of a frame of steel tubes covered with silk, Other smaller planes attached to this make up a surface of 5,500 square feet. There is one great central plane, and to this are hinged various other planes, very much smaller, which are used for keeping the equilibrium correct, and for keeping the flying-machine at a fixed angle in the air. The whole apparatus, including the steering gear, is 145 feet long. A part of the aëroplane, or actual kite, is made of very thin metal, and serves as a very efficient condenser for the steam.

"It is ready and awaiting my return. It is now resting on a track eight feet wide and half a mile long, in my park. The first quarter of a mile of the track is double—that is to say the upper track is three inches above the lower one. By that means I am able to observe and measure the lift of the machine when it starts, because the upper track will hold it down when it lifts off the lower one. When completed the machine will weigh, with water, tanks and fuel, somewhere between 5,000 pounds and 6,000 pounds, and the power at my disposal will be 300 horse-power in case I wish to use it; but it is expected that about forty horse-power will suffice after the machine has once been started, and that the consumption of fuel will be from forty pounds to fifty pounds per hour. The machine is made with its present great length so as to give a man time to think; its length makes it easier to steer and to change its angle in the air. Its quantity of power is so enormously great in proportion to its weight that it will quickly get its speed. It will rise in the air like a sea-gull if the engine be run at full speed while the machine is held fast to the track; and if it is then suddenly loosened and let go."

In an article published in the *Century Magazine* for October, in 1891, Mr. Maxim gives us some description of his engines and boiler. "I have come to the conclusion," he says, "that the greatest amount of force with the minimum amount of weight, can be obtained from a high pressure compound steam engine, using steam at a pressure of from 200 pounds to 350 pounds to the square inch, and lately I have constructed two such engines, each weighing 330 pounds. . . . . These engines are made throughout of tempered steel, and are of great strength and lightness (and designed to yield 300 horse-power). The new feature about my motors, however, is the manner of generating steam. The steam generator itself, without the casing about it, weighs only 350 pounds. It is self-regulating, has 48,000 brazed joints, and is heated by 45,000 jets, gas being made by a simple process from petroleum. When the machine is finished the exhaust steam will be condensed by an atmospheric condenser, and made of a great number of thin metallic tubes arranged in such a manner that they form a considerable portion of the lifting surface of the aëroplane. The greater part of the machine is constructed from thin steel tubes. I found that these were much more suitable for the purpose than the much-talked-of aluminum; still I believe that if I should succeed in constructing a successful machine it would lead to such improvements in the manufacture of aluminum products that it will be possible to reduce greatly the weight of the machine."

In a private letter to Mr. Chanute, October 6, 1892, Mr. Maxim gives some further details which have since been made public in the *American Engineer*. "For fuel," he writes, "I employ naphtha of seventy-two degrees Beaumé. This naphtha is pumped into a small vertical boiler heated with a part of its own contents.

"The vapors from the boiler are led directly to an air injector, where they escape under a pressure of thirty-five pounds per square inch. The mixture of air and gas is then burned through rather more than 6,000 gas jets under the boiler. Steam might be also mixed if required. The distributing of the flame is very even, and it is possible to fill the whole fire-box with a purple flame. With two screws, each 17 feet 10 inches in diameter, and with 300 pounds to the square inch, the machine was made to pull on a dynamometer, 1,960 pounds. If we multiply this pull by the number of turns per minute that the engine makes and by the pitch of the screws we find that the engines develop 300 horse-power.

"The complete weight of engines, boilers, pumps, generators, condensers, and the weight of water in complete circulation, amounts to eight pounds to the horse-power and this of itself I consider quite an achievement. . . . The whole machine is mounted on steel wheels, eight feet gauge, and springs are interposed between the machine and the axle trees; both forward and back axle-trees are attached to a dynamograph, which makes a diagram of the lift of the machine as it advances upon the track. The drum which holds the paper turns once round in 1,800 feet, and whatever the machine lifts either forward or back is recorded upon the paper drum. One of the drums is also provided with a pencil which makes a diagram of the speed at which the machine is traveling."

Mr. Maxim has made frequent trials of his flying-machine at speeds of twenty-five to thirty miles an hour and reports that it can easily lift itself from the track with the exertion of but half its power. In a test described by him last spring, three men and 500 pounds additional weight were placed on the machine to hold it down; yet at a speed of twenty-five miles an hour the forward part of the machine was raised from the track and the total lift was recorded at 6,000 pounds.

Mr. Maxim complains that he is very much hampered for room and thinks that he should have a circular or oval track at least a mile long. With this advantage he thinks that he could solve the remaining problems of stability and steering so as to launch safely into the air and alight safely. He thinks these experiments would occupy him about two years and cost $50,000 to $100,000.

[*To be concluded.*]

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from p. 227.*]

It is no longer necessary to undertake to answer the arguments of those who take the ground that a proper mental training, and hence, a proper education, is only to be attained through the pursuit of classical and literary studies; and that the tendency of a course of study which deals with science and the applications of science to the industrial work of the world, is to exercise a narrowing rather than a broadening influence upon the student, unless it be preceded or accompanied by a classical and literary course.

This matter has been the subject of a vast amount of discussion, especially among professional educators, and among those who devote a good deal of time and thought to a study of different systems of education and their effects, particularly as regards the mental development of the pupil.

It is now generally, if not universally, admitted that, not only can a good mental training be attained by a variety of different courses of study, but also that in order to give to any individual the best mental training possible for him, and hence the best education, the course which he should pursue should depend upon what is variously termed his natural aptitude, his bent, or what he has a taste for; and that if the course of study which he is made to pursue is a different one, his mental training, and hence his education, will be more or less successful in proportion as it is less or more removed from the course which is suited to his natural aptitude.

It is the stage of educational progress marked by the evolution of this idea that has caused our colleges and universities to do away with one fixed curriculum, and to introduce the elective system, *i. e.*, a system of elective studies or elective courses; and so completely has this degree of progress been attained, that the number of colleges that still adhere to one fixed curriculum is very small.

The next stage of educational progress is marked by the evolution of the idea that scientific study, and the study of science as applied to the industrial work of the world, is fully capable of giving the very best mental development to those whose aptitude lies in that direction; and this idea is now very generally conceded, although it had to have a hard fight to gain its position, and there are still a few remaining who oppose it.

The degree of success achieved by the advocates of the new education may best be judged by the enormous development which has taken place in the last twenty or twenty-five years in the scientific and technological schools of the country. Not only has the number of such schools increased very largely, but the increase in the number of pupils in these schools also has been phenomenal. It is thus conclusively proved that there is a very large and rapidly increasing number of persons who choose to give their sons such an education as these schools have to offer, rather than such an education as is offered by the colleges, and who believe that they are thus giving them a better equipment to meet and deal with the problems of life, under whatever circumstances they may be thrown.

But even more evidence is furnished of the prevalence of the idea by contrasting the character of the courses of study offered, and the equipment of these schools to-day, and their condition in these respects about twenty years ago.

It will be evident to any one who will institute such a comparison, even superficially, that the entire drift of the development of these schools has been in the direction of making them more thoroughly scientific, more thoroughly practical, and more closely in touch with the live questions of the industrial work of the day, and the industrial outlook for the future.

In other words, they tend more and more to concentrate the attention and thought of the student upon those subjects that will fit him best for his life-work, making the extent to which other subjects can be introduced dependent upon the time that can be afforded for them consistently with a thorough performance of the work that forms the main objects of the course.

This tendency is not one started by a few educators, which may be lightly charged with lack of wisdom. It is one which has been irresistibly forced upon the schools by the spirit of the age, and which is in the direct line of progress, and, like all other things that are in the line of progress, it cannot be stopped.

Far be it from me to undervalue a thorough classical or literary education, for those whose natural aptitude lies in that direction, or to dispute the desirability, nay, importance, of giving to the engineering or technical student a certain amount of literary training; but I believe that the foremost and principal object to be accomplished by any system of education is mental training, *i.e.*, the development of the powers of the mind, and that this is far better attained by doing some one line of work thoroughly, than by scattering one's energies over a large field. There is no more effective means of imparting to the young man powers of mental concentration, and of fitting his mind to grasp and grapple with the serious work of life, than a course of scientific and practical study. The acquisition of this mental power is the principal object of education, and, if this be neglected, the result is shallowness and not education, even though the student may have done more or less reading, and acquired more or less information on a variety of subjects.

If mental training has been neglected in the education of a young man, it is only with the greatest difficulty that he can repair the damage, and acquire mental power later in life, and, moreover, a greater amount of varied information will not compensate for, nor take the place of, the disciplined power of the mind; whereas, if this has been acquired even by the sacrifice of a certain amount of general reading and information, it is far easier to do this reading later.

Hence, when an engineering course is to be laid out, it should be planned as an engineering course, and should aim to accomplish its object of fitting the student to become an engineer in the best and most thorough manner, and then should be added such general studies as will not conflict with a thorough accomplishment of the engineering work; and the fact should be kept constantly in view that it is mainly on the scientific and practical work of the course that reliance is to be placed to impart mental training; and that, although the general studies are very important, and have their educational value, besides serving to give information, the part they play in giving mental training is far less than the part played by the scientific and practical work.

Another matter, which only of late years has received full recognition, is that the training of the hand and eye forms an important factor in all education, and especially so in a scientific and a technical one. The recognition of this fact is due primarily to the development of the study of science, and especially of applied science; for, in order to make such study successful, it is necessary that the student should observe and experiment, and thus ask questions of nature, and then understand how to interpret correctly her replies.

Thus, the performance of chemical laboratory work by the students with their own hands has been carried out for a number of years in the case of those who were fitting themselves to become chemists. The introduction of physical laboratory work, performed by the students themselves, is of much more recent date; but since its introduction it has been adopted to a very considerable extent, and has proved to be one of the best, if not the very best, means of training the student to perform experimental work with accuracy and thoroughness; to observe, note and collate the facts as they occur; to make measurements with great precision, and to understand and appreciate what are the sources of error that are inevitable, and what are the limits within which the conclusions can be assumed to be correct. The introduction of laboratory practice into the teaching of natural history, of chemistry and of physics constitute a great advance over former methods of teaching science.

But of late years other advances which have been made have exerted a most important influence on technical, and especially on engineering education, namely, the introduction into engineering courses of study, of practice in engineering laboratories, where the student is taught to perform experimental engineering work on a large scale, and under such conditions as occur in practice, thus putting him in touch with the sort of work he is liable to be called upon to do after he enters his profession. Thus, we find, in connection with engineering schools, laboratories for testing the strength of materials, steam laboratories, hydraulic laboratories, mining laboratories, electrical engineering laboratories, chemical engineering laboratories, etc.; and, although they form a comparatively recent addition to the work of engineering schools, their number, their equipments and their efficiency have increased with surprising rapidity during the last few years, so that now there is hardly a school in the country claiming to teach engineering that does not consider it necessary to make an attempt to establish engineering laboratories of some sort.

The other development referred to is the enormous impetus that has been lately given to manual training.

It is true that in France and Germany there have been established for some time what may be called technical schools, which are in no way engineering schools, but more properly trade schools, and that the influence of these schools has been very beneficial to the manufactures of those countries. But the idea of the manual training school is not that of a trade school, but one where, in addition to some more elementary studies of a general and of a scientific nature, the student is taught the use of tools, the object being to educate his hand and eye, to train his powers of observation, to teach him to do work accurately, and to cause him to understand how materials behave by having actually handled and worked with them. And so general has the idea become of the importance of giving this kind of education to children, that not only have large and successful manual training schools sprung up all over the country, but steps have been taken, and are constantly being taken, to give this kind of instruction in the public schools; so that it has already been introduced in many localities, and is rapidly extending.

Even England has waked up in this matter, and displays far more energy than ever before in founding science schools for younger pupils and for artisans. Now, while the product of the manual training school is not an engineer, and while a very sharp distinction should be drawn between the graduate of a manual training school and the graduate of an engineering school, nevertheless, a thorough drill in the use of tools is a matter that the engineer cannot afford to neglect. It develops in him a familiarity with the behavior of materials, which he cannot acquire as well in any other way; it gives him a knowledge of how the actual work must be done, and of what is good and what is poor work; it enables him to know how any piece of work should be carried out, and to judge whether it is satisfactory or will be so when it is finished; so that the instruction given through actual work with tools in the shop is a matter which, unless it has already been taught in the preparatory school, should receive its fair share of attention in an engineering course, although it is not the most important element.

Moreover, all the recent impetus given to a proper training of the hand and eye as an important educational factor, whether it finds expression in the laboratory, in the workshop, in the manual training school, or even in the trade school, is fast removing whatever remnants of prejudice still exist which would cause hand-work to be regarded as degrading, and instead, the world is coming to the conclusion that it is necessary to a proper education, and, hence, honorable in every way, and also that an education is not complete that does not introduce hand-work at some stage.

Whereas the student of engineering of former times found the only courses open to him in the schools that tended to fit him for his profession were such as could be acquired by studying books and listening to lectures, and while he found that books of pure mathematics had been developed to a considerable extent, he found also a great paucity of books that treated in a thoroughly scientific manner of the applications of science to the practice of the profession he desired to enter; the student of to-day finds a far larger supply of books that deal with the live questions of engineering, besides a very extensive and valuable periodical literature, and, as additional advantages, he finds workshops and laboratories of all kinds open to him, opportunities far greater than ever took shape in the wildest dreams of the engineering student of former times.

So rapid has been the increase in the facilities furnished by these laboratories since they began to exist, and so great is the rate at which their scope and material equipment is increasing, that no limit can be set beyond which their development may not carry them, and we may expect them to progress further and further, ever bringing our engineering courses more and more into touch with the live problems of the day, and reacting ever more and more upon the character of the theoretical portion of the instruction by furnishing it with an ever wider basis of experimentally ascertained and experimentally verified fact upon which to build, and thus developing greater and greater opportunities for the education of the young man; and, inasmuch as the law of nature is a constant growth and development, so must these opportunities be ever on the increase, so long as engineering work shall be required by the inhabitants of the world. The foregoing remarks furnish, in an exceedingly brief and general way, a view of the opportunities that can be taken advantage of; and, therefore, the question which presents itself to us, in view of all these possibilities, is, what is, all things considered, the best course of instruction to give a young man who is to make some kind of engineering his life work?

And, first of all, shall we make a more successful man of him by taking advantage of these opportunities, or by merely teaching him to read, write and cipher, and, perhaps, to draw a little, and then, setting him to work in the field, in the shop, or in the draughting-room, to make his own way as our grandfathers did, only rising to higher engineering functions through, and after having fulfilled a long course of practice in the lower, which course sometimes might be called apprenticeship, and sometimes had in it hardly enough of the element of instruction to deserve that name? In other words, shall we undertake to teach him first the scientific principles upon which his life work is based, and then set him to work at it, beginning, of course, at the lowest round of the ladder, or shall we leave him to gain whatever knowledge of principles he may acquire by experience and hard knocks, and only learn to avoid failures by first making them, or else by picking up slowly and laboriously, and in a disconnected way such bits of scientific knowledge as he can at odd moments, stolen from a day full of cares, of anxieties and of business? That a number of the most brilliant stars in the galaxy of the world's greatest engineers have been obliged to follow the latter course, and that in spite of it they have achieved the very highest success and renown, is not to be denied; and they deserve all the greater credit and the higher encomiums for having accomplished all that they did under such adverse circumstances; but I believe that almost, if not entirely, without exception, they would agree that the work they could have accomplished would have been even grander had they had greater educational advantages of a scientific and practical nature in youth, and that they would have saved a great deal of time and hard work if they had been taught early the experience of the past, and the scientific principles and facts of nature so far as they were known at the time, instead of having to steal time from their all-absorbing occupations to pick them up little by little.

I am fully aware of the fact that discussion after discussion has taken place upon this subject, and argument after argument has been advanced both for and against each of these methods of preparing a young man to take up the profession of engineering. To undertake an enumeration of all the discussions that have been held, or of all the arguments that have been put forward, would be an endless task, and I shall not weary you with any such attempt.

It is true that a great many of these arguments are wholly irrational and unworthy of consideration. But we should be careful, in considering them, to do so in a judicial spirit, and not to stamp as wholly irrational everything that is put forward against our own views, and as wholly reasonable all arguments advanced in their favor.

What we ought rather to do, is to begin by separating and laying on one side all the arguments that are wholly absurd and irrational and unworthy of consideration, and then to take up and weigh carefully those advanced by persons who are capable of serious thought, and who have such experience or knowledge of the facts as entitle them to have an opinion on the subject, and who have, therefore, some real or imagined reason, or some partial reason for the arguments which they advance.

Devoting our attention to these, we should endeavor to put ourselves into such a frame of mind that we can realize and understand what are the facts upon which their authors base their conclusions, and to appreciate the point of view from which they look at these facts, real or supposed; and then we shall be better able to pass judicial judgment upon the questions whether their assumed facts really exist, whether they are such as existed at one time and have ceased to exist now, and whether their conclusions are correctly drawn from their observed facts.

That there have been many, and are still a few, men of experience, and of at least fair intelligence, who have taken ground against an education in a scientific school as a preparation for an engineering profession, is a fact not to be denied; but it is also a fact that any such opposition on the part of the experienced and intelligent portion of the community is far less to-day than it formerly was, and what little opposition there is left is fast disappearing, and changing to hearty approval.

In trying to analyze the discussions and arguments against engineering education, we may attempt a certain crude classification, as follows:

(1) There are those who proceed from ignorance and prejudice, and the phases of this ignorance and this prejudice are so varied that it is only possible to enumerate a few.

(*a*) There is always a good deal of talk about the dignity of labor, and it is true that, in the older state of society, labor was thought to degrade a man, but the reaction from this false position has led to the view taken by some ignorant people that any occupation which involves the use of a man's brain, whether accompanied or not by the use of his hands, is degrading. The difficulty with these people is that they do not understand that manual labor is not by any means the only kind, nor is it the hardest kind of labor; neither do they understand that unskilled or unintelligent manual labor is of far less value in doing the work of the world than manual labor performed with intelligence.

(*b*) There is the stupidity and obstinacy of the man who, having become accustomed to one way of doing a thing, is ready to oppose any scheme or proposition which is liable to lead to the conclusion that some other way may be found better than his, and who is especially opposed to any innovation if proposed by some one who has reasoned it out by the use of scientific principles which the former does not possess.

To this class belong a good many who oppose the use of new and improved machinery. It is needless to say that, inasmuch as the world always progresses, such a position as the above injures most the one who holds it.

(*c*) There is another class who systematically oppose the introduction of labor-saving devices, on the ground that the introduction will diminish the work to be done, and, therefore throw a number of people out of employment. They do not realize that the final result is to provide more time for the workers to accomplish a larger amount in the way of results by their labor; for it is a fact that, as labor-saving machinery has been introduced, the comforts and convenience of the entire community have increased, and the very objectors would be unwilling to put up with only such comforts as were available in olden times when no labor-saving machinery had been introduced.

(2) A certain number look to the past, and because there have been men who, with imperfect means at their command, have achieved success and renown, they believe that the course most conducive to success is to imitate them in all external particulars; and that because they accomplished what they did with little early education, therefore, the young men of to-day will succeed best by having no better education.

They do not realize:

(*a*) that their success was accomplished in spite of difficulties and in the absence of early advantages, and not because of them; and that their spirit of indomitable energy caused them to conquer the difficulties with which they were surrounded, and to utilize to the fullest extent all the advantages that they possessed; and that the same indomitable energy would have led them to utilize to the fullest extent a greater number of advantages had they possessed them.

(*b*) that the world is ever progressing, and that, therefore, the new conditions that arise in consequence of this progress present ever new problems to the engineer to solve, which require a knowledge of the experience of the past, and that the more of this experience, in other words, the more science, the young man is already familiar with, the better will he be prepared to meet and grapple with them.

(3) As a rule, an engineer who has started in life without

an engineering education, especially if he has had a fair degree of success, realizes the importance of such an education, knows that he could have accomplished more if he had had it, and desires that the younger generation should have better advantages, and be better equipped for their start in life than he was for his, knowing that if the sons were not to make more progress than their fathers, the advance of civilization would soon be at an end. Nevertheless, every now and then we find some engineer, usually one who is not very able, who values so highly his own accomplishments that he is willing to set them up as a standard for future generations, and knowing that he has reached this standard, although he had no engineering education, he therefore concludes that neither should they have such an education.

It is unnecessary to say any more to show the utter fallacy of the objections stated above; and when we omit a consideration of these, and proceed to analyze the rest of the arguments that have been advanced, I think we shall find, if we read them carefully, that, as a rule, their authors do not object to an engineering education, and, indeed, deem it very necessary and desirable; but they intend their objections to apply to some specific kind of education, the details of which they deem ill-advised or unsuitable. Indeed, I recently undertook to analyze carefully a long discussion of this sort, in which the author made such a number of careless and even contradictory remarks, that to any one who read only certain of his articles it would appear that he did not believe at all in an engineering education. But I found that, after all, he did express himself elsewhere as fully approving such an education and emphasized its importance, and interpreted what he had said that appeared to contradict this idea as meaning simply an objection to certain features of such a course as he imagined was carried on in some places.

Moreover, we should remember that engineering schools are of comparatively recent growth, and that they have been constantly improving their courses, adapting them more and more to the needs of the student who is to enter the engineering profession, so that the courses given in these schools to-day are far different from those given twenty years ago, when engineering schools were still in their infancy.

Having disposed of the objections to such a course, it seems hardly necessary to present many more arguments than those already advanced in its favor. So much progress has been made in engineering science, and so great have been the developments and improvements in the ways of doing work, that when an engineer undertakes work of any considerable importance, he is obliged, in order to accomplish it properly, to make use of so many kinds of engineering—and hence to be familiar with the scientific principles governing them—that it has become practically an absolute necessity that if a young man is to enter the engineering profession with any chance of ultimate success, he should start with an engineering education already acquired.

The importance of such an education has been urged over and over again by a host of the most prominent engineers, and in the most positive terms. As an example, I may cite the address made by Sir John Fowler, before the British Institution of Civil Engineers, upon assuming the presidency of that institution in 1866. This address was devoted entirely to the education of the engineer, and it was deemed of so great value and importance that it was reprinted and very widely circulated.

I will quote a few remarks taken here and there from that address. He enumerates some of the most important engineering works which were being carried out or planned at that time, and he says:

"All these works present problems of great interest, and it will require cultivated intelligence, patient investigation, and enlarged experience, to accomplish the task of their satisfactory solution;" and again: "In the solution of these problems, thus rapidly indicated, and in others which could easily be adduced, we may rest perfectly satisfied that the difficulties they present are not to be overcome by a stroke of genius, or by a sudden happy thought, but they must be worked out patiently by the combination of true engineering principles, ripe experience, and sound judgment."

And, later on, just before he presents his idea of the kind of course he would prescribe, he says:

"We, of the passing generation, have had to acquire our professional knowledge as best we could, often not until it was wanted for immediate use, generally in haste and precariously, and merely to fulfil the purpose of the hour; and, therefore it is, that we earnestly desire for the rising generation those better opportunities and that more systematic training for which in our time no provision had been made, because it was not then so imperatively required."

But the best evidence of the necessity of such an education is the great demand which exists for the services of the graduates of engineering schools to-day. In our own case, *i. e.*, that of the Massachusetts Institute of Technology, notwithstanding the fact that the increase in the numbers of our students during the last few years has been phenomenal, the number of our graduates from year to year does not begin to keep pace with the demand for them, and the heads of the engineering departments are constantly in receipt of a much larger number of requests for them than can be supplied. Also, those who carry on industrial establishments in this country find that it pays them best to have as assistants young men who understand scientific principles, and who are consequently able to take a certain amount of responsibility, and who, therefore, can grapple with an emergency; for, in a live industrial business, emergencies are constantly arising, which can only be met by clear judgment and a knowledge of scientific principles, and the heads of these establishments have less and less use for men who are merely drilled in performing one operation, and know only that; so that this latter class of men are less and less in demand in this country.

In England, the above-stated condition of things is not yet realized, but the facilities for an engineering education are increasing, and there is a constantly increasing sentiment in favor of it. Moreover, the influences at work are such as cannot fail to bring about, before a very great while, the same condition of things as exists now in America.

The next matter for consideration is the nature of the course of study that should be pursued by the prospective engineer. In the preceding lectures I have enumerated and described a variety of engineering industries and of establishments where engineering formed at least a large part, and often the greater part, of the work to be done. The cases cited furnish examples of a number of kinds of engineering, commonly defined by the qualifying words civil, mechanical, mining, metallurgical, electrical and chemical, and perhaps some other industrial operations which are not usually classed with engineering.

If we analyze carefully the work to be done in all of them, we shall find that in many, and I might almost say in all, there are, first, certain processes to be carried out in order to manufacture the desired products, as, for instance, the various processes of melting, filtering, decolorizing, drying and granulating, through which sugar must be carried in a sugar refinery; the series of chemical processes to be pursued in making soaps or glycerine; the metallurgical processes necessary in the manufacture of steel—the proper mixtures of ores, fuel and flux, the proper furnace treatment, etc. Second, we shall find that attention must be given to devising and preparing the means for carrying on these processes efficiently and cheaply; such as designing and building suitable furnaces, machinery, etc.; not solely for the purpose of carrying on the process, but also for a proper and economical handling, so that as little labor as possible may be necessary in receiving the raw materials at the works, in transporting that which has just completed one process to the place where it is to undergo the next, and in getting the finished product out of the works to the consumer or to the market.

This matter of economical handling is one of the most important items about a manufactory, and involves a careful consideration of the proper arrangement of the machinery in the works.

Then arise the questions respecting the best kinds of machinery to use for all the steps in the process, including a consideration of its efficiency, durability, first cost, the expenses necessary for attendance, also for its maintenance and repair; the expenses necessary for labor in the performance of the several processes, including the labor of handling, of loading and unloading, of transporting, etc.

Next comes the consideration of the nature, construction and arrangement of the power plant, whether water or steam power, or both, are to be used. If the former, the proper constructions, such as dams, canals, locks, etc., to bring the water to the wheels, and to discharge it when it leaves them, proper wheel-house, and selection of wheels.

If steam is to be used, the choice of the kind of engine, whether there shall be one or more, and where it or they shall be located, depend upon the character of the work to be done and the uses for steam in the works.

All these matters must be carefully considered with a view to efficiency and economy in the long run. The selection of boilers, the erection of chimneys, boiler-house, engine-house, etc., are all important questions.

Then comes the construction and arrangement of the whole power plant; and next, a consideration of the proper system of transmitting the power from the various sources of power to the different points in the works where it is to be used, whether by shafting, gearing, belting, cotton or manilla ropes, wire ropes or electric dynamos and motors.

Then we shall have to determine the proper design and construction of buildings adapted for the work, including proper foundations for them, proper water supply, proper drainage, proper heating and ventilation, proper light in daytime and when daylight is either not available or not available in sufficient quantity, fire protection, as well as a large number of questions of a similar character, all of which are generally recognized as engineering questions, and of which it would be almost impossible to give a complete list.

In the infancy of manufactures the processes are liable to be the all-absorbing problems, *i. e.*, by what processes to produce the required result; but as any one of these manufacturing interests develops, the processes become more or less a settled thing, or, at most, the opportunities for variation from one fixed method are few, and all manufacturers have to conform more or less closely to this fixed method.

When this state of things is reached, the manufacturer who would succeed is forced to pay attention to the engineering problems that arise in his business; and a failure to solve these problems satisfactorily results in very serious loss to the concern, and may more than eat up all the profits.

If, in view of all the above, we were to attempt to define the different kinds of engineering previously referred to, viz.: civil, mechanical, mining, metallurgical, electrical and chemical engineering, and to designate certain kinds of engineering work as belonging to one or the other of these professions exclusively, we should find that, after all, there is no dividing line between them and that much of the work is common to all of them. Hence, these distinctions, so far as they refer to a classification of engineering work, are purely artificial. Moreover, a man cannot be a successful mining engineer, a successful metallurgical engineer, a successful electrical engineer, or a successful chemical engineer, unless he is an engineer well versed in the science and practice of engineering.

We might then define the mining engineer as the man who performs the engineering work in any of the mining industries; the metallurgical engineer as one who performs the same duties for a metallurgical works, and so on.

The mining engineer, in order to be able to do his work properly, must be versed in the processes to be followed in mining operations, otherwise he will fail to appreciate what are the objects to be accomplished, and hence he will not properly adapt his engineering work to the required ends; and so, also, in the cases of the other kinds of engineers mentioned.

Hence, the mining, the metallurgical, the electrical, or the chemical engineer must be, primarily, an engineer, but he must also be sufficiently versed in the special mining, metallurgical, electrical or chemical processes, to be able to adapt his engineering work to their needs.

When we come to the terms civil engineering and mechanical engineering, both of which, at different times have been used in different senses, and both of which have often been used to denote the engineer as I have described him, it is impossible to draw a line, and to assert that any one set of engineering operations belongs exclusively to the civil or to the mechanical engineering profession. Indeed, the term civil engineer has been used at different times to denote all grades, from the thoroughly equipped engineer to the mere surveyor, who knows no engineering at all. Hence, it would not be worth while to attempt to give the various definitions that have been proposed for a civil and for a mechanical engineer. So various and arbitrary have been these distinctions that, according to some, the building of wooden ships belonged to the civil, and that of iron ships to the mechanical engineering profession.

According to the ideas at the present time, generally prevalent among those who make a distinction between the two, it may be said that the work of the civil engineer is associated with the design and erection of what might roughly be called public works, as roads, railroads, bridges, canals, improvements of rivers and estuaries, lighthouses, water supply, sewerage, irrigation, etc.; and that the work of the mechanical engineer is that of dealing with machinery. Hence, the person who had charge of and performed the engineering work for machine shops, for cotton mills, woollen mills, silk mills, flour mills, rolling mills, metallurgical works, manufactories of steam engines of all sorts, whether stationary, marine or locomotive, manufactories of all sorts of machinery, chemical manufactories, motive power and rolling stock departments of railroads, etc., would be called a mechanical engineer.

If, however, we should adopt these as definitions, and proceed to determine the kinds of work which each one would be liable to be called upon to perform, we should find no class of engineering problems that would not probably arise in the work of either the civil, or the mechanical engineer. To illustrate, take the case of the Forth bridge. You will remember that very large machine shops had to be planned, built and operated; that enormous amounts of machinery had to be used; that a very large portion of it was special machinery, which had to be specially designed and built, and operated under very peculiar circumstances. There were required a number of power plants, including steam engines, steam boilers, etc., all of which had to be built and operated; compressed air had to be produced and used in very large quantities; electric light plants had to be established and operated; a large number of cranes had to be built and operated by power; and an enormous amount of engineering work had to be performed, which, if one attempted to make a distinction, would usually be classed as mechanical rather than civil engineering, and it would be at least a question whether it was not more than the remainder of the work. In the case of bridge work generally, we should find the same condition of things existing in different degrees, according to the circumstances of each case.

Next, if we take up the subject of foundations and of drainage, which usually would be considered as pertaining strictly to the province of civil engineering, we shall find at once that the man who has charge of the engineering work of almost any large manufactory is frequently liable to have to put in a foundation, and every now and then it is a difficult one, to be built to support very heavy loads, and he may even be called on to build foundations under water, as, for instance, when the structure is on the water's edge, or on the shore, and where suitable works must be built to allow vessels to approach it to discharge or to take on their cargoes.

From what has been said it seems to me clear that no line can be drawn which marks off the work of the civil from that of the mechanical engineer, and that the kinds of problems which both are liable to have to solve are largely the same.

[*To be continued.*]

SOME RECENT CONTRIBUTIONS TO OUR KNOWLEDGE OF METALLIC REDUCING AGENTS.*

By H. F. Keller.

In the extraction of metals from their oxygen compounds, carbon is certainly the most important and useful reducing agent. Its great affinity for oxygen is utilized in the manufacture of iron and steel; the commercial production of other useful metals such as copper, lead, zinc and tin is accomplished, either directly or indirectly, with its aid; and under its influence even the energetic metals of the alkalies release their powerful grip upon oxygen. Contrasted with this the use of other substances for the purpose of abstracting oxygen is almost insignificant. Is it surprising, therefore, that carbon is looked upon as the reducing agent *par excellence*, or that the very idea of reduction seems to us inseparably associated with this element?

But the reducing power of a substance, depends in a large measure upon temperature. It is well known to chemists that, under certain conditions, many metals have affinities which are far more powerful than those of carbon. When we glance over the pages of our chemical text books, we see described there numerous experiments based upon the superior combining power of iron, aluminum, zinc, magnesium and the alkali metals. The great Swedish chemist who arranged the elements according to their supposed affinities in an electro-chemical series, was among the first to employ the positive alkali-metals for isolating and preparing other elements. His method consisted in decomposing the halogen compounds by means of potassium; and it was subsequently improved by Berzelius' distinguished disciple, Wöhler. With its aid the latter chemist not only succeeded in reducing for the first time those remarkable metals aluminum and beryllium, but he also showed that *all* those metals, the oxides of which cannot be reduced by either carbon or hydrogen, may be obtained by the action of potassium upon their halogen compounds.

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* Read at the stated meeting of the Chemical Section, held January 16, 1894.

It must not be supposed, however, that the use of metals as reducing agents is confined to the laboratory and the lecture table. Practical applications of such reactions may be less conspicuous, but they constitute, nevertheless, the basis of not a few important metallurgical processes. The "precipitation" of lead from its sulphide ores; the solution of silver by the nascent lead in the blast furnace; the amalgamation of the same metal in the iron pan; Deville's process of extracting "silver out of clay," recently so greatly perfected by Castner and Netto—are they not essentially reductions by means of metals?

In view of the facts mentioned, it may appear strange that comparatively little progress was made for many years in the study of the reducing properties of metals. We can, however, satisfactorily account for this when we consider the great tendency of metals to form alloys; it is difficult, in many cases indeed impossible, to obtain products entirely free from the reducing metal, and it is also well known that even a trifling amount of such impurity may seriously impair the valuable qualities of a metal. Another obstacle has been the high price of those metals, which, by reason of their more powerful affinities, could with advantage be substituted for carbon.

Recent improvements in the commercial production of some of these metals have partially removed the latter obstacle. Thanks to the rapid progress of electro-metallurgy, aluminum is now to be had for about half a dollar per pound; sodium, once a chemical curiosity, is manufactured on an enormous scale at a less cost even than aluminum; and magnesium now, successfully extracted from carnallite is, applied to a variety of technical uses.

The radical changes which have taken place in our views on chemical affinity as a result of the study of thermochemical phenomena, and the theory that the properties of the elements are *periodic functions* of their atomic weights, have also largely contributed to awaken interest and activity in the subject of our discussion.

The remarkably high heats of formation of its oxide and chloride, as well as the great stability of these compounds, render the action of magnesium upon other oxides and chlorides particularly interesting. Clemens Winkler, of Freiberg, has presented us with a most careful and systematic investigation of the reducing action of this metal upon oxides, while Seubert and Schmidt have communicated a similar exhaustive study of its action upon chlorides.

In giving a brief résumé of the results obtained by these experimenters, I shall adhere to the order adopted by them. It is based upon the periodic system, and has the advantage of showing many interesting relations that might otherwise escape notice.

GROUP I.

Group I embraces a main group consisting of Li, Na, K, Rb, Cs, and a sub-group consisting of Cu, Ag, Au.

Owing to the difficulty of obtaining the oxides of the alkali metals in a pure condition, the carbonates were employed. It was found that to insure the best results three atoms of magnesium are required for every molecule of the carbonate, thus: $Na_2 CO_3 + 3 Mg = 3 Mg O + C + 2Na$.

The carbon as well as the sodium are deprived of their oxygen. It was found that, with the exception of $Cs_2 CO_3$, the alkaline carbonates *suffer reduction* to the metallic state when heated with Mg, but that the intensity of the reaction diminishes as the atomic weight of the metal increases. Li, *e. g.*, whose atomic weight is only seven, was reduced with explosive violence, the metal being completely vaporized, while the tube in which the reduction was effected was shattered to pieces; potassium (at. weight 39), and rubidium (at. weight 85) on the other hand, were reduced quickly and without notable vaporization.

The reduction may be made in a tube of hard glass closed at one end; it is better observed, however, by conducting it in a current of hydrogen.

The preparation of potassium affords a most instructive experiment, which may well serve for lecture demonstration.

Into a wide tube of Bohemian glass, a porcelain boat, containing about two grams of the mixture of K_2CO_3 and Mg is introduced. A current of perfectly dry hydrogen gas is passed through the tube, and the part of the tube surrounding the boat is gradually heated to incipient redness; the mass darkens, and upon further raising the temperature with the aid of the blast lamp, the reduced potassium is completely expelled from the boat, exhibiting the deep green color of the vapor, and is deposited in the form of a bright mirror in the cooler part of the tube. At the same time the hydrogen flame shows an intense violet color. The dark residue remaining in the boat consists of magnesia and carbon. Enough potassium will have collected to show its color, lustre; that it is sectile, fusible; its action upon water, bromine, etc.

In view of the high price of metallic potassium, the question as to whether the described reaction might not be carried out on the large scale suggested itself. Experiments showed, however, that in the absence of a gas current, the distillation of the metal is very incomplete; and inasmuch as carbon monoxide forms an explosive compound with this metal, illuminating gas could not be substituted; in fact, the explosive carbonyl-potassium was invariably formed when the quantity of magnesium present was insufficient for the *complete* reduction of the carbonate.

This was further proved by experiment. When two atoms only of Mg were taken, the reaction took place according to the equation:

$$\mathrm{CO}\begin{matrix}\mathrm{OK}\\ \mathrm{OK}\end{matrix} + 2\,\mathrm{Mg} = \mathrm{CO} + 2\,\mathrm{K} + 2\,\mathrm{MgO}.$$

More promising results were obtained by employing KOH instead of K_2CO_3. The danger of forming the explosive body is thus avoided, while the H gas set free simultaneously with the K, ensures the complete distillation of the latter.

$$\mathrm{KOH} + \mathrm{Mg} = \mathrm{K} + \mathrm{H} + \mathrm{MgO}.$$

The reaction is somewhat violent, but may be moderated by adding some inert substance, such as magnesia; or by using the magnesium in the form of lumps or bars.

Winkler says "it does not seem unlikely that the manufacture of potassium could be carried out by means of the same apparatus, and the same operations, which C. Netto has so successfully employed in reducing caustic soda with carbon. Into a retort filled with bars of magnesium, and heated to redness, melted potash would be allowed to flow in a continuous stream, while the escaping mixture of potassium vapor and hydrogen is being cooled."

Winkler figures the cost of one pound of potassium to be about $3.75; the metal is now quoted at $28.

Beketow, who had previously made use of the action of Al upon KOH, obtained only one-half of the theoretical yield owing to the simultaneous formation $KAlO_2$.

The sub-group consisting of the heavy metals Cu, Ag, and Au exhibited the reverse behavior; the reduction was more energetic the higher the atomic weight of the metal. A very *slight* deflagration accompanied the removal of O from cuprous oxide, while Ag_2O was reduced with *explosive violence*. Very curiously aurous oxide was not visibly affected by the magnesium. This is explained, however, by the fact that Au_2O splits up into its constituents considerably below the ignition point of Mg.

GROUP II.

The main group comprises Be, Mg, Ca, Sr, Ba; and Zn, Cd, Hg, constitute the sub-group.

These elements are divalent, and the action of their oxides upon Mg is therefore:

$$R''O + Mg = MgO + R''.$$

In some cases the *hydroxides* were also used.

Beryllia was easily reduced by Mg; the mass became slightly incandescent, but some unaltered oxide was found in the residue.

There was no action observed when a mixture of Mg and MgO were treated in H; the oxide remained in the boat, while the metal sublimed in beautiful crystals. The existence of Beetz's suboxide could not be confirmed.

No visible sign of chemical action occurred when lime and Mg were heated together. The reduction proved nevertheless to be almost complete.

A slight incandescence attended the reduction of strontia, whilst oxide of barium displayed an energetic action upon Mg. In both cases the decomposition was apparently complete.

None of the alkaline earth metals were found to be volatile at the temperature of reduction.

The hydroxides were even more readily acted upon than the oxides; so striking and beautiful, indeed, were the phenomena observed in the cases of $Ca(OH)_2$ and $Sr(OH)_2$, that Winkler proposes to utilize them for lecture illustration, and in pyrotechnics.

The reduction of the oxides belonging to the sub-group was very energetic, the resulting metals being vaporized completely. Cadmium oxide develops less energy than either zinc oxide or magnesium oxide.

Both in the main group and the sub-group, the maximum of chemical energy occurs in the second member.

GROUP III.

The main group embraces B, Al, (Sc), Y, La, Yb; Ga, In, Th, form the sub-group. Three atoms of magnesium are required to abstract the oxygen from their oxides:

$$R_2O_3 + 3\ Mg = 3\ Mg\ O + 2K'''$$

Phipson has observed that boric acid is reduced upon ignition with magnesium. With the aid of Mg, boron was also obtained by Geuther from the boro-fluoride of sodium, and quite recently L. Gattermann has shown that boric acid, as well as borax can be reduced by means of this metal, so as to yield products which are suitable for the preparation of various boron compounds.

Winkler confirmed these observations. He states that the trioxide and the borate of sodium are easily reduced, the latter with much energy and evolution of sodium vapor. But he found that, instead of free boron, the residue contains magnesium boride of variable composition; for, on treatment with hydrochloric acid, hydride of boron is given off as a gas. Sometimes a solid residue remains, which is likewise a compound of boron and hydrogen.

Owing to the acid-forming character of boron, the reduction was never complete; borates, upon which magnesium has no action, are always formed.

An attempt was also made to prepare a sub-oxide of boron by limiting the supply of Mg, thus:

$$B_2O_3 + Mg = 2\ BO + MgO$$

but no indication of such an oxide was observed.

A dark colored product resulted from heating alumina with magnesium. The reaction appeared to be quite energetic; the mass exhibited a vivid glow and increased largely in volume. In addition to finely divided aluminum, a new oxide, AlO, and magnesium spinelle had been formed. This monoxide could not be obtained in a pure condition, but its existence was proved beyond doubt. It is best prepared by heating in a current of hydrogen, a mixture corresponding to

$$Al_2O_3 + Mg = 2AlO + MgO.$$

This oxide is a brownish-black, voluminous powder, is pyrophoric, and liberates H slowly from water; it precipitates cuprous oxide from copper sulphate solution, and is exceedingly susceptible to oxidation.

Winkler suggests that the blue color of sapphire, and possibly also that of ultramarine, may be due to a small proportion of this monoxide.

Of the rare earths of group III., only yttria and lanthania were subjected to the action of magnesium. The energy of the reduction appeared to increase with the atomic weights.

Upon the oxides of the sub-group, Mg reacts with great violence; the intensity of reduction has its maximum in In_2O_3.

The behavior of Th_2O_3 towards magnesium, appears to be an exception. Before the temperature of reduction is reached, this oxide splits up into Th_2O and O_2, and the thallous oxide so formed is then only partially reduced. The carbonate of thallium, however, is deprived of its O completely and with explosive violence.

GROUP IV.

The most interesting results, perhaps, were obtained in the fourth natural group of elements.

The known properties of C, Si, Ti, Zr, Ce, Th, assign them positions in the main group, while Ge, La, Pb, constitute the sub-group.

In addition to their acid-forming dioxides, the majority of these elements are capable of giving monoxides. It was therefore deemed desirable to attempt not only the complete reduction of the higher oxides, but also a *partial* removal of the oxygen with a view to procure the lower oxides.

The statements of different experimenters concerning the action of CO_2 upon Mg are somewhat conflicting.

That a ribbon of the metal will burn in an atmosphere of CO_2 was first observed by Kessler, but neither he nor other chemists who repeated and modified his experiment explained satisfactorily the nature of the reaction.

Winkler shows, in the first place, that magnesium, when *moderately* heated in a current of CO_2, does not take fire, but is slowly converted at its surface into a carbide, CO being formed at the same time. Upon increasing the heat to a full redness, the metal was inflamed and continued to burn with a dazzling light. The products of this combustion are MgO and C.

When the magnesium is employed in the form of powder, these reactions take place even more readily. At a temperature considerably below a red heat, CO appears and its quantity is greatly increased when low redness is reached. The metal burns with great brilliancy at a full red heat, and unless the current of CO_2 is very rapid, its reduction is complete.

It has already been mentioned that a separation of C was observed when Mg acted upon carbonates; also that CO was formed when an excess of the carbonate was present. Further experiments were made with calcium carbonate. A mixture of this substance with magnesium: $Ca\,CO_3 + 3\,Mg$

$= Ca + C + 3\ MgO$, heated in a current of H, detonated violently. A carbide of magnesium was observed among the debris. No Ca was observed in the residue when only 2 at. of magnesium were used for each molecule of the carbonate.

According to Kessler, burning magnesium is extinguished in CO, while Parkinson asserts that at a red heat the metal burns vividly in this gas. Both observations were found to be correct. A spiral of magnesium wire ignited in the air, ceased to burn while introduced into a jar of CO, but when strongly heated in a current of the gas the magnesium emitted light, and a gray coating of a carbide appeared on its surface.

Numerous experiments to determine the exact composition of this carbide were made, but without yielding a definite result.

Silicon exhibits a pronounced tendency to combine with Magnesium. Silicon-magnesium was first observed by Wöhler, in 1858.

The reduction of SiO_2 by metallic magnesium was observed 1864, by Phipson, and Parkinson has shown in 1867 that silicon-magnesium, as well as a silicate of magnesium, are formed at the same time. A few years ago L. Gattermann published an interesting paper, in which he showed how very easily silicon dioxide is reduced by magnesium. He states that either silicon or silicon-magnesium can be obtained by varying the proportion of magnesium; and he applies the reaction to the preparation of volatile compounds of silicon, such as the chloride, bromide, iodide, silicoformic acid, silico-chloroform, etc.

Gattermann and Winkler agree that an energetic reaction occurs upon heating a mixture of one molecule of SiO_2 and 2 atoms of magnesium.

$$SiO_2 + 2\ Mg = Si + 2\ MgO.$$

By adding MgO to the mixture, the heat of the reaction was moderated, but it was then found that much silicon-magnesium was contained in the product. If the reaction be effected at low temperature and in the presence of an excess of magnesium, silicon-magnesium was always formed, while at a high heat or in presence of magnesium, only amorphous silicon resulted.

A monoxide of silicon could not be obtained by the reduction of silica, either by magnesium or silicon.

Many silicates are reduced quite as easily as the dioxide; in some cases the metallic base is likewise reduced, *e. g.*, potash glass.

None of the oxides studied presented greater difficulties than titanium dioxide. The results may thus be summed up: TiO_2 was not reduced to the metallic state; a mixture of monoxide and a titanium spinelle were the products of the reaction. Other intermediate oxides were sometimes formed. When the residue was treated with HCl, HTi_3O_4 was formed, which, upon treating, gave TiO_3 and H. Neither titanium-magnesium, nor a hydride of titanium, was observed.

The reduction of zirconia was effected by heating it with magnesium to a high temperature. A monoxide could not be identified with certainty; and $ZrMg_2$ does not appear capable of existing.

According to the amount of Mg employed either Ce or Ce_2O_3 were obtained from cerium dioxide. An intermediate monoxide was not obtained. The reduction begins at a moderate red heat and is accompanied by a vivid glow. A considerable proportion of the Mg is volatilized. In the nascent state cerium was found to absorb hydrogen in large quantities.

The formation of a metallic hydride at a bright red heat is a most remarkable observation. It is clearly proved to be correct by the following experiment.

A mixture is prepared according to the equation:

$$CeO_2 + 2Mg = Ce + 2 MgO.$$

Twenty grams of this mixture are placed in a combustion tube through which a current of dry hydrogen is passed, while a gentle heat is applied to expel any moisture. The further end of the tube is then closed with a strong clip.

Hydrogen is allowed to enter the other end and the heat quickly raised to bright redness; a rapid current of hydrogen is seen to pass through the wash bottles into the tube.

The hydride is of a brownish-red color. It is without action on water at ordinary temperatures, but sets free hydrogen upon heating. Hydrochloric acid dissolves it to CeCl, with evolution of hydrogen. It was found impossible to completely remove MgO from the product. The hydride is very imflammable, and detonates with $KClO_3$, KNO_3, etc.

The analytical results obtained point to the formula CeH_2.

After the existence of a hydride of cerium had thus been established, the thought suggested itself that the other elements of group IV. might possibly be capable of forming similar compounds. Only carbon and silicon were known to form hydrides, but these elements could not be made to unite with hydrogen when their oxides were reduced by magnesium. Since titanium could not be reduced to the metal, it is not strange that all efforts to form a hydride gave negative results, zirconium and thorium did absorb hydrogen and yielded hydrides similar to CeH_2. The same was observed with lanthanum and this led Winkler to believe that this element belongs to the cerium group; but he showed subsequently that yttrium and other trivalent elements, and even the divalent barium, strontium and calcium can unite with hydrogen.

These hydrides represent a new class of metallic compounds, in which only half the usual valence of the metals is satisfied.

The action of magnesium upon chlorides has been made the subject of an elaborate research by Seubert and Schmidt.

I must content myself with a very brief statement of some of the main results obtained by these chemists.

Both the anhydrous bodies and the aqueous solutions of the chlorides were subjected to the action of magnesium.

In the former case, the substance, either mixed with magnesium powder, or conducted over it in the form of vapor, was heated to a high temperature. It was found that all chlorides could thus be reduced to the metallic state, but the reduction was incomplete in the groups of the metals of the alkalis and the metals of the alkaline earths.

In *neutral* aqueous solutions, all the metallic chlorides, save those of the alkalies and those of the alkaline earths, gave up their chlorine to the magnesium. In some cases the metals were deposited in the metallic state, (Ag, Au, Tl, Pb, As, Sb); but in most cases, hydroxides were precipitated. These hydroxides always represent the lowest state of oxidation. $CuCl_2$, *e. g.*, is changed into Cu_2O; Ce, Au, Fe, Mn, all yielded hydroxides.

It would seem that the tendency to form such hydroxides is peculiar to the positive metals, and especially to those forming basic salts. Seubert and Schmidt believed this to be due to a dissociation of the chlorides into hydroxides and hydrochloric acid. They suppose, for instance, that an aqueous solution of $AlCl_3$, contains $Al(OH)_3, 3HCl$. This view is rendered quite probable by the fact that solutions of Cu, Ni, Co, and Cr exhibit the color of their *hydrated* salts.

Of other metals whose oxides possess a high heat of formation, aluminum has found some application in the reduction of oxides. Beketow has employed it with success to prepare some of the metals of the alkalies; and the experiments of Greene and Wahl of reducing manganese oxides by means of the metallic aluminum are still fresh in our memory.

I am convinced that a continued study of the relative affinities of the metals for oxygen and other negative elements, will lead to important applications in metallurgy, and give new and valuable methods to synthetic and analytical chemistry.

BOOK NOTICES.

A Treatise on Elementary Hydrostatics. By John Greaves, M.A. Cambridge University Press. 1894. Price, $1.10.

A school-book, modeled after the excellent works of Rev. J. B. Lock, upon mechanics and mathematics, published by the Messrs. Macmillan. As is proper in such a work, each chapter is followed by a number of practical examples for solution. The book embraces chapters upon capillarity and upon the statics of gases. T.

The Chronicle Fire Tables for 1894. A record of the fire losses in the United States by States and Territories during 1893, etc. New York: The Chronicle Company, Ltd. Price, $5.

This large octavo volume of reliable annual fire data comes in suggestive crimson binding, with over 400 pages. The general arrangement is similar to that of former years. It shows, *inter alia*, the progression of the total annual fire losses. In 1890, they amounted to $109,000,000; 1891, $144,000,000; 1892, $152,000,000; and in 1893, the largest of all, $168,000,000. To see these immense losses properly arranged and classified for study and reference, and to know that it is all accurately done, is not only encouraging to the efforts of those using such data, but is a source of real satisfaction. The diagrams and tables herein, showing the quantity and movement of fire losses in the United States for twenty years, are very interesting and become annually more so.

A remarkable fact is shown in one of the tables—that though the actual increase in fire losses, 1890 to 1893 inclusive, has been so great, as above shown, there has been a steady diminution of the *average* property fire loss from $7,285 in 1885, to $4,761 in 1893; and in the *average* insurance loss, from $4,069 in 1885, to $3,012 in 1893. This shows, mainly, that improved fire-extinguishing apparatus, improved modes of building, and increased care of fire underwriters, are showing their good effects. Without such efforts and improvements, had these matters gone on as ten or fifteen years ago, the fire losses would probably have reached $250,000,000 in the United States for 1893.

The principal excellent tabulations show the fire losses in each State and Territory by classes of risks. There is a general table showing the number of fires by classes, property loss and insurance loss, with all the known causes by numbers (together with the unknown) appended to each class. This, though not as long as others, is one of the very best of the tabulations. Another general, and similarly arranged table, gives the fires and losses by causes (the last-named put first) and appended is the character of each risk where the fire originated. Another similar table gives the fire and losses by specified industries.

There are many other tabulations, and some graphic diagrams which we would like to mention, but want of space prevents. In brief, this standard annual is fully up to the merit of its other recent issues, and in some respects shows improvement thereon. We unhesitatingly recommend it as containing the best arranged and the fullest fire data obtainable anywhere, and we pronounce the "Chronicle Fire Tables" to be superior to any other such data yet attempted in the world. N.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 19, 1894*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Sept. 19, 1894.

PROF. E. J. HOUSTON in the chair.

Present, seventy-two members and twenty-four visitors.

Additions to membership reported since the stated meeting of June, 1894, twenty-two.

The Secretary presented a communication from a committee appointed by the Royal Society of London, to inquire into, and report upon, the feasibility of preparing, by international co-operation, a complete catalogue of scientific publications, and requesting the views of the Franklin Institute respecting the project. On motion, it was voted to refer the matter to the Committee on Library, with the request to give it proper consideration, and with authority to transmit its conclusions to the Committee of the Royal Society.

After lengthy discussion *pro* and *con*, the following amendments to the by-laws of the Institute were adopted, viz.:

On the recommendation of the Board of Managers

ARTICLE II, Section 1 (paragraph 4).—Amended by striking out the words "*three* dollars" and substituting in place thereof the words *six* dollars.*

ARTICLE III, Section 6.—Amended by striking out the words "*fifty* cents" and inserting in place thereof the words *seventy-five* cents.

ARTICLE IV, Section 1.—Amended by striking out the words "five dollars," and inserting in place of them the words "eight dollars;" and further by striking out the words "fifty dollars," and inserting in place of them the words "one hundred dollars."

ARTICLE IV, Section 4.—Amended by striking out the words "fifty cents," and inserting in place of them the words "seventy-five cents."

Offered by Mr. Henry R. Heyl:

ARTICLE III. *Members.*—Amended to read as follows:

SECTION 1.—The members of the Institute shall consist of manufacturers, mechanics, artisans, and persons friendly to the mechanic arts, and they may be either annual contributors, life members, permanent members, holders of second-class stock, honorary or corresponding members.

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*Adopted by vote of the stockholders present.

SECTION 3.—The privileges of membership in the Institute shall extend only to persons of legal age who are not in arrears and who shall have signed the charter and by-laws.

ARTICLE IV. *Payments.*—Amended to read as follows:

SECTION 1.—The annual dues of contributing members shall be eight dollars; a life membership (not transferable) may be acquired by the payment of one hundred dollars within any one year, and a permanent membership may be granted to any one who shall, within any one year, contribute to the Institute the sum of one thousand dollars, which membership may be transferred by will or otherwise.

SEC. 5.—The annual dues from contributing members may be applied to the current expenses of the Institute, but all moneys received from life and permanent membership shall be vested in the Board of Trustees, the income therefrom only to be applied to the maintenance fund.

Mr. Alfred Goldstein presented a paper on "A Standard System of Automatic Fire-alarm Protection," illustrated by a working specimen of the apparatus employed, exhibiting the operation of the system. The system is that of The Pneumatic Fire Alarm Telegraph Company, and has received the endorsement of the Board of Fire Underwriters in various cities. The Hall of the Institute is protected by this system. (Referred for publication.)

Mr. W. N. Jennings exhibited some striking photographic views of the new Tower Bridge over the Thames, at London. Description of an exhibit of some remarkable aluminum castings, made by William S. Cooper, of Philadelphia, was deferred on account of the lateness of the hour.

Adjourned. WM. H. WAHL. *Secretary.*

ERRATUM.

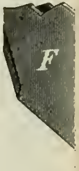
Article.—Kebler, Interaction of Borax, etc. On p. 238, September, 1894, several errors occur in the equations. The correct reading is given below:

(1) $2C_3H_5(OH)_3 + Na_2B_4O_7 = 2C_3H_5BO_3 + 2NaBO_2 + 3H_2O$.

(2) $2C_3H_5(OH)_3 + Na_2B_4O_7 + 3H_2O = 2C_3H_5(OH)_3 + 2H_3BO_3 + 2NaBO_2$.

(3) $C_3H_5BO_3 + 3H_2O = C_3H_5(OH)_3 + H_3BO_3$.

(4) $3Na_2CO_3 + 2H_3BO_3 = 2Na_3BO_3 + 3CO_2 + 3H_2O$.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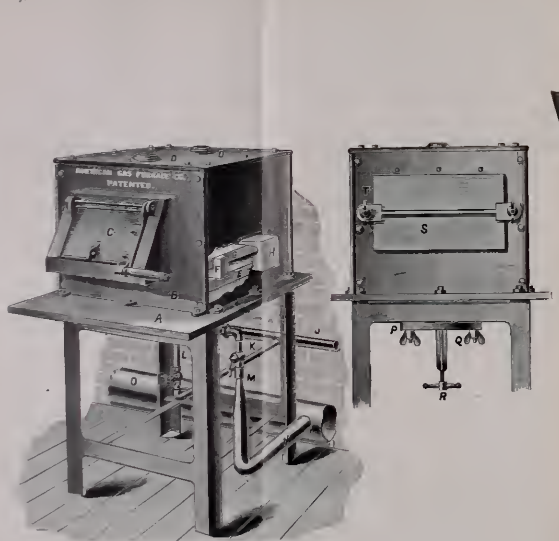
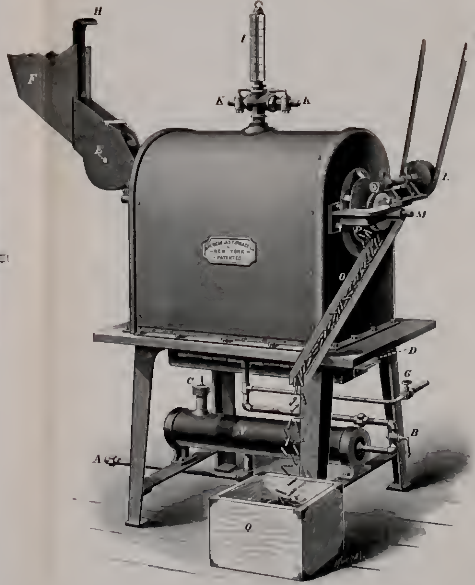
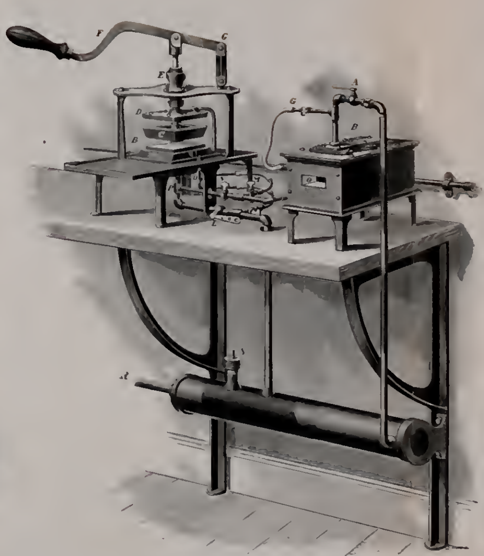


OVEN FURNACE NO. I.

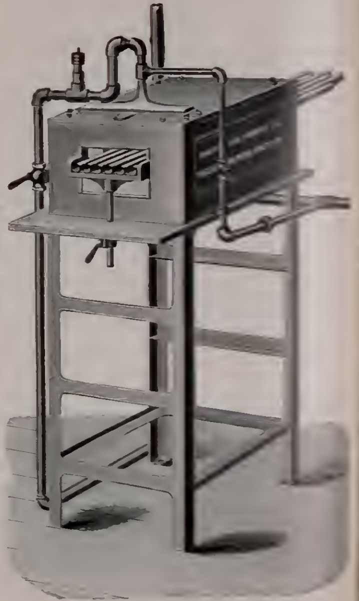


AUTOMATIC TEMPERING AND COLORING FURNACE.



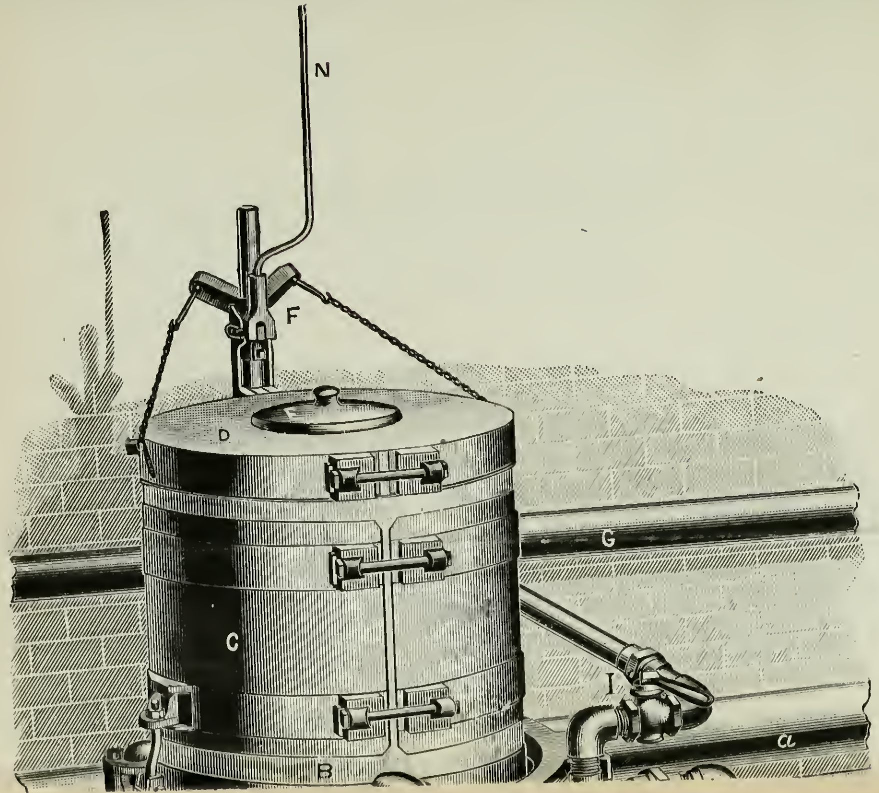
BLANK ANNEALER AND WATCH-CASE FLATTENER.

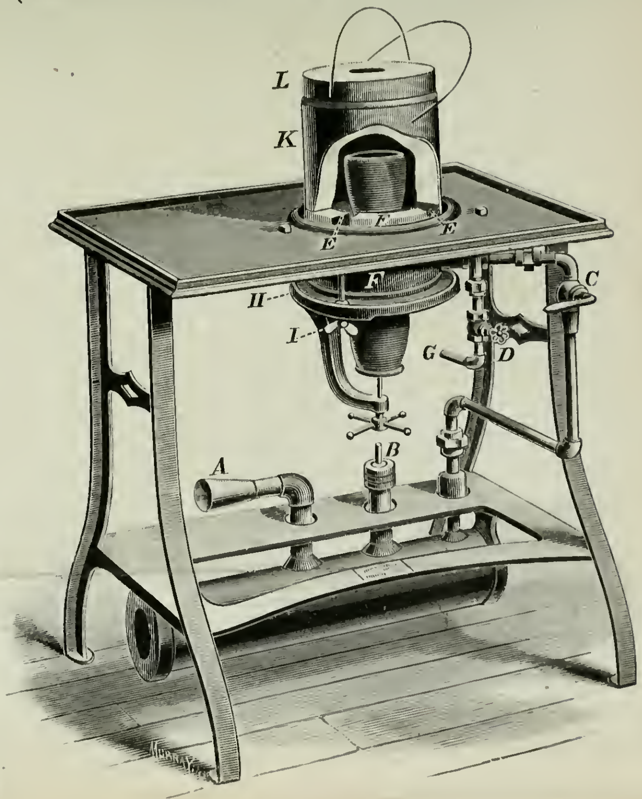
TUBE SOLDERING FURNACE.

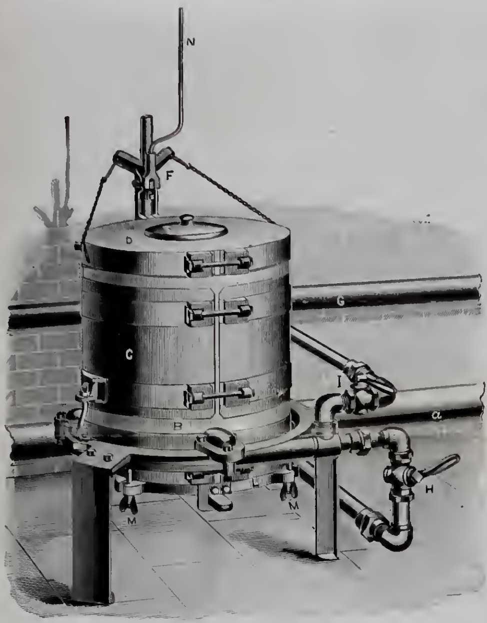


FURNACE FOR SOLDERING BRASS TUBING.

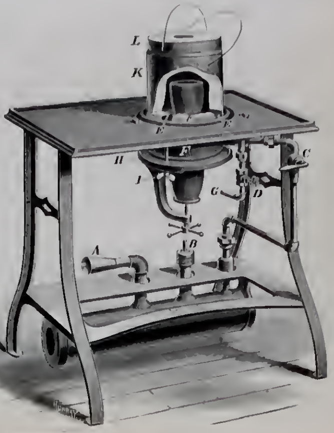
Jour. Frank. Inst., Vol. CXXXVIII. November, 1894. Plate II. Report No. 1781. (American Gas Furnace Company's System and Apparatus.)



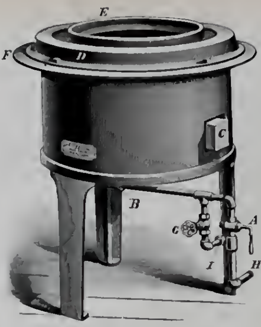




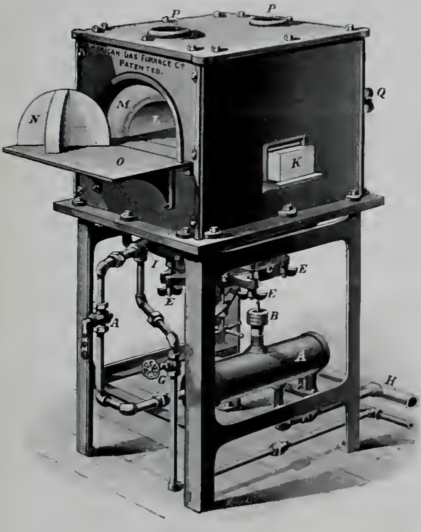
LARGE CRUCIBLE FURNACE.



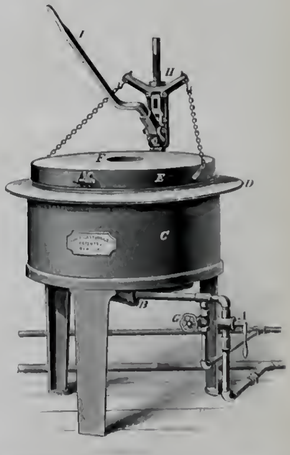
MELTING FURNACE.



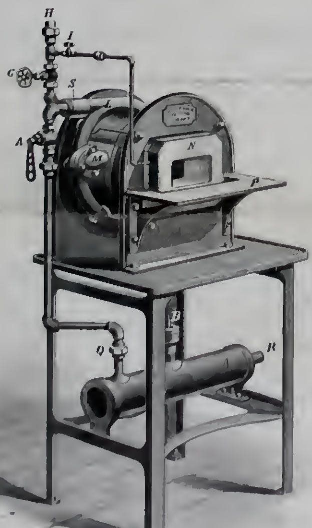
SOFT METAL FURNACE.



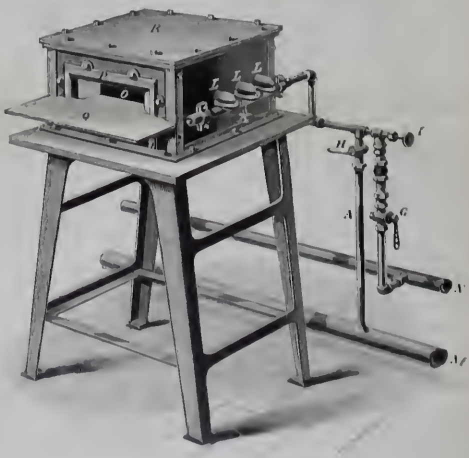
MUFFLE FURNACE.



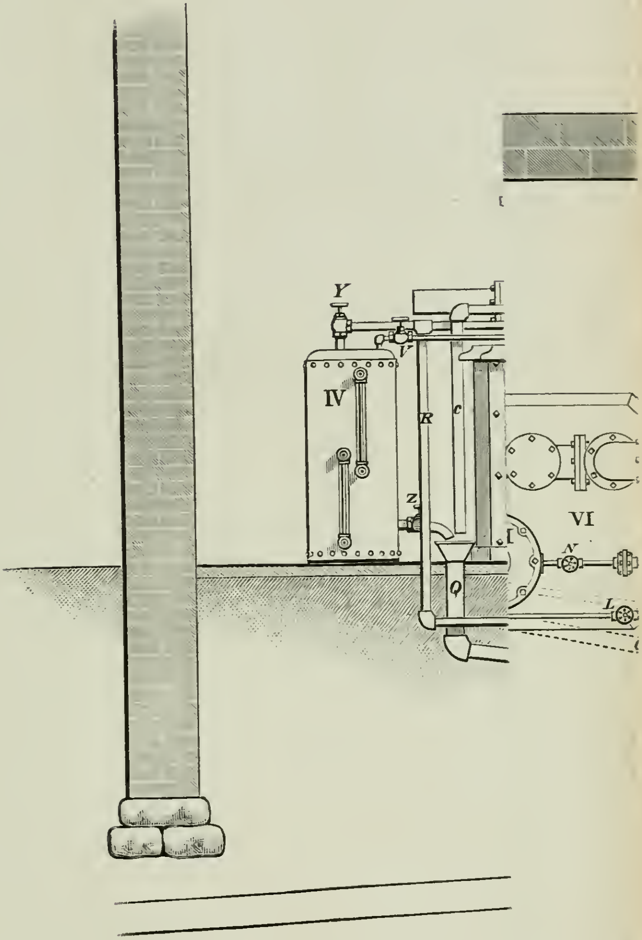
ROUND ANNEALER.

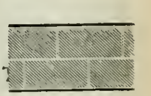


GAS FORGE NO. 3



GAS FORGE NO. 4





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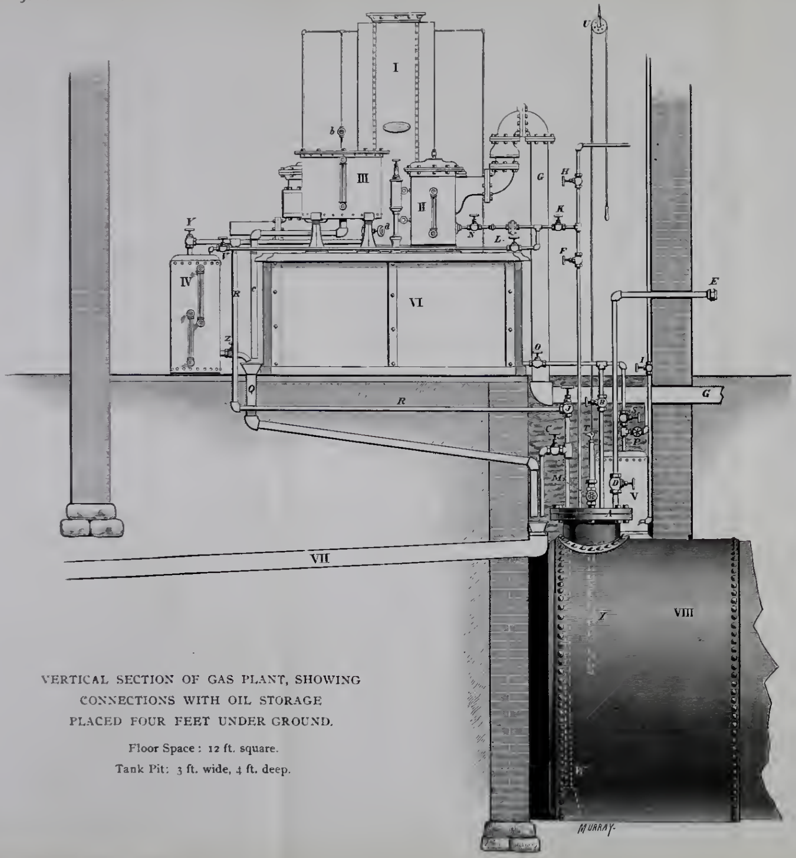
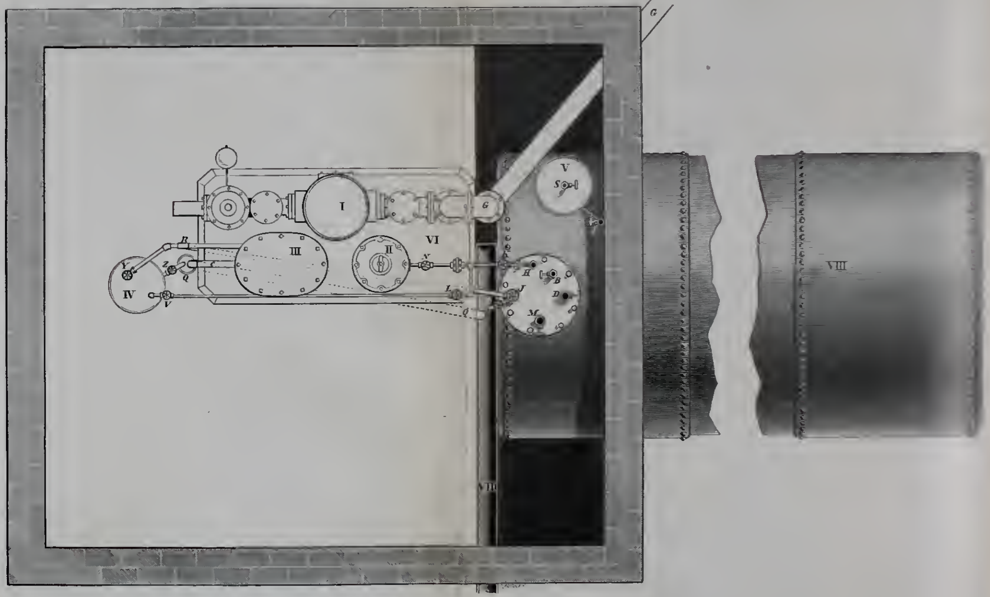
Floor Space : 12 ft. square.
Tank Pit: 3 ft. wide, 4 ft. dee



VERTICAL SECTION OF GAS PLANT, SHOWING CONNECTIONS WITH OIL STORAGE PLACED FOUR FEET UNDER GROUND.

Floor Space: 12 ft. square.

Tank Pit: 3 ft. wide, 4 ft. deep.



GROUND PLAN OF GAS PLANT.

Interior Space of Gas House, 12 ft. square, 12 ft. high.

JOURNAL

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VOL. CXXXVIII. NOVEMBER, 1894. No. 5

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THE AMERICAN GAS FURNACE COMPANY'S FUEL GAS SYSTEM AND APPARATUS.

[*Being the report of the Committee on Science and the Arts on the inventions of Messrs. E. P. Reichhelm and George Machlet, Jr.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 6, 1894.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the American Gas Furnace Company's "system for producing fuel gas and its application in the production of heat for mechanical work,"

Finds that the application embraces a system of generating and utilizing gaseous fuel for mechanical purposes, and consists essentially of three parts, to wit:

(1) a fuel gas generator;

(2) a blower for the regulation of pressure in the generator and at the points of consumption; and

(3) the furnace in which the heat of the gaseous fuel is utilized.

The patents submitted with the application of E. P. Reichhelm, President of the American Gas Furnace Company, are the following:

No. 405,051, June 11, 1889, to E. P. Reichhelm, for a gas furnace;

No. 464,779, December 8, 1891, to E. P. Reichhelm and George Machlet, Jr., for an apparatus for, and method of, making fuel gas; and

No. 502,890, August 8, 1893, to E. P. Reichhelm, for a rotary blower.

The special features of the system of the Amerieau Gas Furnace Company consist in the production of a rich fuel gas in quantities determined in each case by the demand, and which fuel gas is consumed in the furnaces as rapidly as it is generated without employing storage reservoirs; and in the simple and practical means employed for ensuring the control of the proportions of the mixtures of air and gas, and of the rate of combustion, by the regulation of the air pressure.

The gaseous fuel is produced from naphtha, the cheapest product of the petroleum refinery, by an improved method of atomizing the liquid, which ensures the complete vaporization of all the oil supplied to the storage tank, and the condensation and separation of substantially all the moisture contained in the air employed in the operation. The rate at which the gas is produced, also, is under control, and may be varied according to the requirements of each case. The oil delivered to the atomizing apparatus is displaced by water in the storage tank situated below the lowest level of the remainder of the plant, so that no air space is permitted to exist in which explosive mixtures of air and oil vapor could form, and no flooding of any part of the plant by accidental injury or leakage is possible. The gas is conducted to the furnace and there consumed as rapidly as it is generated, thus making the use of gas holders for its storage unnecessary, and practically eliminating the difficulty of condensation which otherwise would have to be provided for.

The manner in which the naphtha is "atomized" in the Reichhelm-Machlet generator is very effective. The inventors employ an apparatus having a series of vertically disposed screens, each successive screen being finer than its predecessor, thus ensuring that nothing but air saturated with vaporized oil shall be carried into the pipes; also, the heating of the entering air blast is an ingenious artifice by which the condensation of the contained moisture and its precipitation in solid form, which would otherwise take place in the atomizing chamber, is avoided.

The features involved in the control of the combustion at the points of consumption will be found concisely stated in the following account quoted substantially from the explanatory letter filed with the application:

The object which the inventors have steadily sought to realize in the practical development of their system, has been to provide a simple means of ensuring the intimate mingling with the fuel of a sufficient quantity of air, to produce perfect combustion. With solid fuel such intimate mixture is practically impossible to attain unless the fuel is first pulverized and injected together with the air, into a combustion chamber, under pressure. With gaseous fuel, there is no difficulty in bringing the two elements together in any desired proportions, and hence to obtain practically the full value of the fuel in heating effect.

The inventors claim to have been taught by the results of experience that to obtain an exact mixture of air and fuel in any desired proportions, it is necessary that such mixture should be made *back* of, and not *at*, or *near to*, the point of combustion. Accordingly, in the gas furnaces here considered, provision is made for the preliminary thorough admixture of the gas and air, and its injection under regulated pressure as a definitely-proportioned mixture into a combustion chamber specially adapted as to size and form for the work to be done, and with a vent or outlet conformed strictly in size to that required for the free discharge of the products of combustion. The manner in which the flame is admitted to the furnace also has certain advantages which will be referred to elsewhere.

The system, as has been stated, involves the delivery of the fuel gas and air to the point of combustion under pressure, and the inventors claim in connection with this operative feature, that although the great importance of a perfectly steady, continuous and powerful air blast, under positive control, had been theoretically well known, it has been realized to its fullest extent for the first time in this system.

To meet the requirements of the system in the most satisfactory way, the special form of blower described in United States Patent No. 502,890, above referred to, was devised, which can be operated at great speed, and is substantially noiseless. While not an essential part of the system (and therefore need not be referred to in detail), it nevertheless contributes to its usefulness.

The furnaces in which the heat of the flame is utilized, vary very greatly in size and construction according to the special service for which they are required. A feature which is applied wherever the nature of the service will permit, consists in disposing the inlet pipes admitting the air and gas mixture into the furnace chamber, tangentially, with respect to the walls of the furnace. By this artifice, the flame does not impinge directly against the crucible or other article to be heated, but sweeps round it, thus insuring that all parts of the crucible shall be equally heated, and avoiding the injurious effects of over-heating the crucible and its contents in parts, which is liable to occur when the flame is permitted to strike directly against it.

The system of the American Gas Furnace Company appears to have been worked out, by careful and intelligent attention to details, in a manner very creditable to its originators, and the results obtained from its practical application on an extensive scale in a large number of industrial establishments, by the uniform testimony of their managers, demonstrate a high efficiency in heating effect, complete control of the temperature to suit the work in hand, very desirable cleanliness, and a satisfactory economy.

The list of establishments which have adopted the system of the American Gas Furnance Company, embraces such well-known houses as the Meriden Britannia Company, of Meriden, Conn.; Pope Manufacturing Company, of Hartford, Conn.; Elgin National Watch Company, Elgin, Ill., and the following notable establishments in Philadelphia: Keystone Watch Case Company, S. S. White Dental Manufacturing Company, and the laboratory of the United States Mint.

The sub-committee charged with this investigation has had correspondence with the representatives of the above-named manufacturers and others, to ascertain to what extent, if any, the system of the American Gas Furnace Company demonstrated superiority over the methods for which it had been substituted. The tenor of a number of answers received is uniformly very favorable. The sub-committee, by arrangement, paid a visit to the factory of the S. S. White Dental Manufacturing Company, at Frankford, where a complete plant of the applicant is installed, and where every process required for manipulating steel in the manufacture of fine dental instruments is performed with the applicant's fuel gas in furnaces of special design. The sub-committee was given the opportunity there, of examining every detail of the system, and was very favorably impressed with its operation.

The conclusion reached respecting the merits of this system from the data submitted, is that while it exhibits no radical departure from well-established principles, it is, taken as a whole, an efficient, perfectly controllable, and economical system of generating and utilizing fuel gas, which has amply demonstrated its utility in practice.

The Institute accordingly recommends the award of the John Scott legacy premium and medal to the inventors, Messrs. E. P. Reichhelm and George Machlet, Jr.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, June 26, 1894.

JOSEPH M. WILSON, *President*,
WM. H. WAHL, *Secretary*.

Countersigned

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

APPENDIX.

The accompanying plates of illustrations are presented for the purpose of throwing light upon the text of the foregoing report.

Plate I exhibits a vertical section of the gas generating plant, showing connections with the oil storage tank placed four feet under ground, and also a ground plan of the same.

Plates II and *III* exhibit a few of the various forms of furnaces designed for special uses. A brief description of these furnaces is given in the following:

The melting furnace (*Plate II*) is designed principally for jewellers' use, for melting gold and silver, for assay work and small melts of copper, brass, etc.

The furnace proper consists of three principal parts, the bottom *F*, the burner ring with burner tips *E* projecting into it, and the cylinder *K*, which rests upon the bottom *F* by its own weight. The bottom contains the support upon which the crucible stands, and is slotted underneath so as to cover, but not obstruct, a passageway in the bottom to the crucible, which is screwed against it from below, to receive leakage or overflow. Combustion products escape through *V*. All parts are detachable and easily replaced. Blast pipe connects at *A*; gas, $\frac{3}{8}$-inch pipe, at *G*. *B* is the pressure relief valve.

The large crucible furnace has substantially the same construction. The cylinder *C* and bottom *B* are encased in sheet-iron cylinders, held together by clasps *Q*, which can be opened to replace the linings. This furnace is used for melting large quantities of gold and silver, brass, copper, steel, etc.

The soft metal furnaces have the same general features as the crucible furnaces. They are comparatively larger in diameter, and the heat is consequently less concentrated. The iron pot *E* rests by a flange on the ring *D*. The combustion products pass off by a vent at the rear, with which a chimney connection may be made. Gas and air connections are at *G* and *A*.

The gas forges shown are designed for dressing and hardening tools, small forgings, etc. No. 3 is especially recommended for drop forgings to heat blanks continuously and keep them at the proper heat. The burner is such as is used in melting-furnaces, but is disposed in vertical position.

The muffle furnace shown is adapted for heavy work requiring high heats.

It is entirely encased in cast-iron framework bolted together, with heavy linings of fire-clay sections. The square casing is filled in above and around the arch with non-conducting material to lessen radiation, and the muffle bottom is protected by an extra bottom slab, to prevent its sagging under weight.

Air connection is made to a nipple on the drum *A*, from a blast pipe *H*. Gas connects by $\frac{3}{4}$-inch pipe from a 1-inch supply pipe under the valve *G*. The entrance *M* is through a heavy front lining, and is closed by a solid plug *N*. The lighting hole is closed by the plug *K*.

The round annealing furnace is used principally for annealing coils of wire or plate, circular disks of steel, round dies and cutters for hardening. It is formed of a cylinder with heavy fire-clay lining, closed by a cover operated by a "cover lift." It has a double bottom by which it is divided into two compartments, of which the lower one is the combustion chamber. It is intended to be kept in continuous operation, so that work can be annealed instantly by simply swinging back the cover, placing the coil or annealing box on the bottom and replacing the cover. The work can be watched through the hole in centre of cover. The heat is controllable by the gas and air valves, so that articles may be annealed evenly and thoroughly, without risk of melting or burning. By this apparatus oxidation is reduced to a minimum.

The oven furnaces (*Plate III*) are designed to heat a square or oblong space of any desired dimensions evenly throughout, to any required degree, from cherry-red to white heat, and to maintain the required temperature steadily. They may take the place of muffle furnaces except where the absolute seclusion of the work from the products of combustion is necessary. They are used for heating cutters, dies, reamers, shears and knife-blades, saws, and for annealing all kinds of work of steel, iron, brass and other metals.

The oven furnace, shown in the plate, has an inside space available for work 18 inches deep, 16 inches wide and 8 inches high. The entrance, closed by door *C*, is 12 inches wide and 6 inches high. A fire-brick slab *G*, supported by the fire-brick *F*, separates the interior of the oven into two chambers, the "combustion chamber" beneath the slab, and the heating chamber above it, in which work is placed. The combustion chamber has a burner similar to those of the melting furnaces, which enters a funnel-shaped well-hole in the bottom where the combustion takes place. The whirling motion of the flame drives the heat outward from the "well," and the fire-clay slab *G*, which is placed at the proper height above the burner, secures its even distribution, The heat is thence forced into the upper chambers, by passing around the sides of the slab through a narrow interval or slot between the side walls and the edges of the slab.

No flame should enter the upper chamber when the gas supply is properly adjusted. The advantage of these furnaces over a muffle is the more immediate and direct action of the heat upon the work, the lessened cost of running by dispensing with costly and perishable muffles, and their adaptability to larger work.

The automatic tempering and coloring furnace is designed for tempering or coloring small steel articles in large quantities. The work is fed in measured quantities from the hopper *F*, into a revolving scoop *E*, at every revolution of which the work it contains falls into the end opening of a spiral way, contained within a revolving cylinder, which is perforated, and is enclosed within an outer cylinder revolving with it, and containing sand. The articles are propelled through the spiral way to the outlet at *M*, and continuously subjected to the action of hot sand sifted upon them until discharged. The temperature is regulated as required for various tempers or colors. The heat is controlled by the burner *D* under control of the gas and air valves *G* and *B*, by the air pressure regulated by the valve *C*, by the vent cocks *KK*, and by the speed at which the revolver is run.

The blank annealer and watch-case flattener is a special form of furnace devised for the purpose named. It is substantially a press provided with an upper and lower disc or die, of shape conforming to that of the object; and which discs are both heated evenly, the upper one *C* from above by burner *D*, and the lower one *B* from below.

The lever *FG* connects with the vertical rod *E*, to which the upper burner *D* and disc *C* are attached. The metal to be flattened is placed upon the disc *B*, and by pressing upon the lever *F*, is annealed and straightened.

The apparatus to the right of the one just described has been designed for soldering small tubings, such as are used for pencil-cases, pen-holders, etc. The burner *B* covers seven inches and directs the flame diagonally from the top to the lower left-hand corner of the heating chamber. The burner is graduated in strength from front to rear, so that the tube joint receives the greatest heat just as it leaves the furnace.

The remaining illustration represents a furnace designed for soldering brass tubing. Its operative features are as follows:

The burner is inserted in the top of the furnace and points downward, with a slant toward the rear, distributing the heat evenly across the full width of the furnace. On passing through the furnace from the rear, the tubing is subjected to a gradually increasing heat until the soldering point is reached, which is about six inches from the mouth of the furnace.

THE PHOSPHATES OF THE WORLD.*

BY FRANCIS WYATT, PH.D.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MR. CHAIRMAN, LADIES AND GENTLEMEN, MEMBERS OF THE INSTITUTE:

The products of nature are the sole sources of our food, and at the same time furnish all the raw materials of art. It is therefore evident that agriculture is the rock upon which nations build their riches, and that its development and prosperity involve the development and prosperity of the whole human race.

The first thing necessary to the cultivation of a people is the accumulation of wealth, as without it there can be no leisure, and without leisure there is no opportunity for cultivating the intellectual faculties, or for acquiring the knowledge necessary to the progress of all civilization. How rapidly such wealth may be accumulated and capitalized, must naturally depend upon the nature of the climate and the fertility of the soil, since the latter regulates the returns made to any given amount of labor and care, while the former regulates the energy and the continuity of that labor.

For example: the only portions of the American Continent which could lay any claim to civilization before the appearance of Europeans, were those comprised in the tract which stretches from the Isthmus of Panama to Mexico in the Northern, and to Peru in the Southern Tropic.

Aside from the questions of geological and chemical varieties of soil, which are of course of paramount importance, the two regulating causes of fertility are combined heat and moisture, the land being fruitful or sterile according to their abundance or deficiency. Now as regards moisture, neither in North nor in South America does one really great river empty itself into the Pacific, the whole of them being upon the eastern coast; and as regards heat, nature has been equally partial in its endowment of the West. Whether the natural difference of temperature resulting from this curious phenomenon forms part of some universal scheme, or whether it is a peculiar instance, is immaterial; the fact and its primitive influence are indisputable, the two great conditions of fertility not having been naturally united in any part of the entire Continent north of Mexico. The inhabitants therefore, either had no heat, or having heat, had no irrigation; and the result was that until the sixteenth century, when the acquired knowledge of Europeans was brought to bear upon the subject, there existed no agriculture, no accumulation of wealth, and no progress north of the twentieth parallel, even toward that rough civilization so easily attained by the nations of India and Egypt.

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* A Lecture delivered before the Franklin Institute, January 12, 1894.

In the narrow tract of land lying south of the twentieth parallel, the conditions were entirely different. Its peculiar configuration caused by the contraction of the Continent until it reached the Isthmus of Panama, secures to it a large extent of coast, and gives to it the character of an island. It had the two features of an insular climate; increase of moisture arising from the evaporation and augumentation of rainfall natural to the vicinity of the sea. This southern part of North America was therefore the only portion possessing in addition to a physically and chemically perfect soil, the natural combination of the two essential elements. Its equatorial situation gave it heat, and the shape of its land humidity; and it arose out of barbarism, and became a centre of early civilization.

This may be perhaps regarded as a far-fetched example to favor an argument, but I think it may be fortified by a glance at the sandy plains of California. Until these were subjected to irrigation by the ingenuity, enterprise and enormous capital of a modern civilized community, they remained in a condition of desert-like sterility; but now that proper and efficient means have been provided for watering them, they display all that marvellous exuberance that characterizes a well-constituted virgin soil where the necessary heat and moisture are not wanting.

It is not, of course, my intention to trace the progress of our agriculture back to those primitive settlers who eventually succeeded in giving a certain value to the land; but I venture to make the broad statement, that until long after the commencement of the present century, the methods of our farmers differed but in trifling details from those of the ancient Romans. They continued to draw upon their immense natural reserves without a thought of the future, and it was only when crops began to fail, and general signs of exhaustion began to make themselves manifest, that they consented to listen to the teachings of science. The acquired knowledge of the geologist, botanist and chemist were, however, eventually brought into play. The researches of Liebig, Lawes, Gilbert, Dumas, Boussingault, Barral, Malaguti, Payen, George Ville and many others were studied and turned to good account; experimental farms and stations were established in all the states; and at the present time I believe that our literature of agricultural science is second to none in value and importance, throughout the whole range of the world's philosophical investigation.

While, however, a goodly minority of our more intelligent farmers have kept pace with this progress, an immense majority—north, south, east and west—have given it no attention, and even look with suspicion and distrust upon those who would enlighten them. They admit the facts, but cannot understand the reason why their annual crops are no longer so abundant, nor of so good a quality as they were thirty or forty years ago.

This ignorance cannot, of course, continue, because we live in an age of thought and of rapid intercommunication. The last barriers of prejudice must be beaten down by experience and example, and before long every farmer must realize that agriculture can only remain a profitable pursuit on the condition that he yearly obtains from his acres a maximum and cheap return.

In order to succeed in this, he must restore to the soil those elements which it once contained in abundance, but which, in the process of nourishing the plants, have been partially taken away.

The food value of all vegetable growths is derived from their starch, gluten, sugar, gum and some organic acids, while the value of animal food is due to albumen, fibrine, fats and small quantities of divers saline matters. All these constitute what are known as proximate principles, the ultimate composition of which is made up of such simple bodies as carbon, hydrogen, oxygen, nitrogen, calcium, potassium, sodium, iron, phosphorus and sulphur. The elements of our food are therefore taken from the air, the water and the soil, and are so fitted together by the plants as to produce the food of those animals termed graminivorous, which, in their turn, afford to us the vast bulk of our animal sustenance. These mysterious inward processes and these marvellous transmutations of inorganic into organic products, through the medium of plants and animals, form the foundation of the phenomena connected with vegetation and the increase and prosperity of populations, and a very practical and beautiful illustration of the contrast existing between the respective attributes of vegetables and animals has been furnished by Dumas and Cahours in the following manner:

Vegetables produce.	*Man and Animals consume.*
Nitrogenous matter,	Nitrogenous matter,
Fatty matter,	Fatty matters,
Gum, sugar, starch.	Gum, sugar, starch.
Vegetables consume.	*Man and Animals produce.*
Carbonic acid,	Carbonic acid,
Water,	Water,
Ammonia.	Ammonia.
Evolve oxygen, constitute apparatus of reduction and are stationary.	Absorb oxygen, constitute apparatus of oxidation and are locomotive.

No argument could better illustrate than this the progressive and eventually complete exhaustion of the soil, and we are naturally brought to realize the necessity for its reconstitution by the aid of chemistry, for the reason that while man and animals produce those very elements which are so necessary to the renewed existence of plants, *they both are locomotive, and do not, in practice, give back to the earth what they have borrowed from its stores.*

Some rough idea of the actual quantity of mineral matter annually withdrawn from the soil by our food plants may be arrived at if we take a given weight of any cereal—say, for instance, wheat, and burn it until it is reduced to a perfectly white ash. If we next weigh this ash very carefully, we shall ascertain that its weight will represent about two and one-fourth per cent. of the material burned. In the same manner if we burn a weighed sample of the straw of the grain, we shall find that the residual ash will represent about six and one-half per cent. of the original substance, and a chemical analysis of the two kinds of ash, wheat and straw, shows that their composition is as follows:

	Wheat.	*Wheat Straw.*
Phosphoric acid	46·30	3·74
Sulphuric acid	2·57	3·40
Chlorine	0·60	3·30
Iron oxide	0·74	0·45
Potash	34·14	18·20
Soda	0·18	0·85
Lime	3·90	5·93
Magnesia	10·40	1·63
Silica	1·17	62·50
	100·00	100·00

In other words the ash of the grain contains phosphoric acid equal to about twenty per cent. of phosphorus, and that of the straw contains phosphoric acid equal to about one and one-half per cent. phosphorus.

Phosphorus is one of the most useful of the non-metallic elements and ranks with oxygen, hydrogen, nitrogen and carbon, in its importance to the animal and vegetable economy. It is not known to occur in the free state on the surface of our globe, but is always found in the form of phosphates, and principally as phosphate of lime, made up of three molecules of lime and one molecule of phosphoric anhydride. To make the combination more clear to those who are not intimately acquainted with chemistry, I may explain that when a piece of pure phosphorus is burnt, in contact with dry air it gives off vapors, every two atoms of which combine with five atoms of atmospheric oxygen to form a snow-white powder. This powder is the phosphoric anhydride above alluded to, and it has a molecular weight of 142. Its chief characteristic is its attraction for water, and if left temporarily exposed to the air it rapidly deliquesces.

In this moist state it is found to have combined with water in the molecular ratio of 1 : 3, and its composition has become:

	Molecules.	*By Weight.*
Phosphoric ahydride (P_2O_5)	1	142
Water (H_2O)	3	54
Phosphoric acid (H_3PO_4)	3	196

In other words 100 parts of this phosphoric acid contains:

	Parts by Weight.
Phosphoric anhydride (P_2O_5)	72·45
Water (H_2O)	27·55
	100·00

And it may be regarded as typical of the tribasic combination in which the anhydride is always encountered in nature.

Phosphoric acid has the faculty of exchanging one, two, or all three of its water molecules for molecules of various bases, and thus we are quite familiar with it as:

$CaO(H_2O)_2P_2O_5$, or acid phosphate of lime, in which it has taken one molecule of lime in place of one molecule of water; $CaO_2H_2OP_2O_5$, or neutral phosphate of lime, in which it has taken two molecules of lime in place of two molecules of water; and $CaO_3P_2O_5$, or tribasic phosphate of lime, in which all the water molecules have been displaced by lime.

The first of these compounds is soluble in water.

The second insoluble in water but soluble in neutral citrate of ammonia.

The third is only soluble in strong acids.

When quite pure every 100 parts of each of them is made up of:

	Acid Phosphate of Lime.	*Neutral Phosphate of Lime.*	*Tribasic Phosphate of Lime.*
Phosphoric anhydride (P_2O_5) .	60·68	52·20	48·81
Lime (CaO)	23·93	41·18	54·19
Water (H_2O)	15·39	6·62	—
	100·00	100·00	100·00

The tricalcic, or last of these compounds, constitutes the bones of men and animals and is the phosphate of lime which is found in nature, and which from the very commencement of time, has been produced, redistributed, and diffused through all cultivable soils. In certain rocks of past ages, it has been accumulated and stored up in enormous quantities.

It has been estimated in a rough and essentially approximative manner that the total area of soil under cultivation for cereals and grasses, in this country and in Europe, is 1,000,000,000 acres, and that the crops attain an average of about one ton per acre. It has also been roughly estimated that the average depth of the soils over this area is in the neighborhood of nine inches, and analyses have shown that their average contents in phosphates are about 4,000 pounds per acre. The total amount of phosphates contained in the soils now under cultivation in America and Europe is, therefore, 2,000,000,000 tons.

Since every ton of crop deprives the soil of forty pounds of phosphate it follows that the 1,000,000,000 tons of crop use up 20,000,000 tons of phosphate every year. Only about half this quantity is recovered from the refuse of farms and cities and returned to the soils; the other half is carried away and lost. This creates a yearly deficit of 10,000,000 tons of phosphate, and in the ordinary course of events the lack of this most essential constituent would entail sterility of all the soils in the next 200 years.

This very serious fact has arrested the attention of some modern farmers and has led them to use a number of phosphatic substances for the purpose of restoring fertility to their lands.

Of these substances I have grouped together a few of the best known, and have placed opposite to them the figures of probable annual consumption, so far as I have been able to ascertain them by diligent enquiry.

Name of Substance.	*Average contents in phosphoric acid. Per Cent.*	*Probable quantity used.*
Guanos of natural origin	25	100,000
Fish, and fish refuse	5	300,000
Tankage and slaughter houses	9	1,000,000
Bones	24	1,000,000
Bone black	32	
Bone meal	30	
Superphosphate of lime	12	3,500,000
Natural phosphate of lime of low grade	20	1,000,000
Refuse of various kinds from tanneries, glue factories, oil works, etc	3	1,000,000

From this data it would appear that the total quantity of phosphates used in these various forms does not amount to more than about one-third of the average amount yearly drawn from the soil, and it consequently follows that there is an actual and active necessity for at least three times the present consumption.

Coming now to the

CLASSIFICATION OF NATURAL PHOSPHATES,

I may point out that those varieties which are found in nature and which furnish all that is now used for commercial purposes are ranged in more or less regular geological order. First, we have the

PHOSPHATES OF THE ARCHÆAN AND PALEZOIC AGES,

which are apatites or crystalline phosphates, and which chiefly occur in the rocks of the Laurentian and Lower Silurian systems. They have been discovered in New York, New Jersey, Maine, Canada, and other places in North America. In Europe they are found in England, France Saxony, Tyrol, Bohemia, Spain and Norway. The only deposits that are sufficiently important to be workable, however, are those of Canada, Norway and Spain.

Apatite chiefly occurs in hexagonal crystalline masses, sometimes very compact and at other times coarse and granular. Its hardness is about 5. and its specific gravity about 3·2. Its color varies from white to yellow, brown, black, green, blue or red, according to the greater or lesser proportion of impurities present. The following examples are

TYPICAL ANALYSES OF APATITES:

	Canada.	*Norway.*	*Spain.*
Phosphate of lime	88·20	86·01	89·22
Carbonate of lime	4·13	3·20	0·87
Fluoride of lime	3·10	4·99	5·01
Chloride of lime		0·70	0·81
Alumina and iron oxides	0·70	0·30	0·43
Magnesia	0·20	0·10	0·23
Insoluble siliceous matters	3·67	4·70	3·43

The total average output of apatites from all sources for the past ten years has not exceeded 40,000 tons per annum, and of this quantity more than one-half may be fairly said to have been produced from the Canadian mines and shipped from Montreal.

The two provinces of Canada which have produced the most phosphate are Quebec and Ontario. In both of these the Laurentian rocks form immense belts which traverse the country for many miles with a N. E. and S. W. trend, and extend downward for twenty-five or thirty thousand feet.

Sometimes these rocks are entirely granitic or hornblendic gneiss, and at others they are made up of pyroxene, feldspar, calcite, mica, pyrites and apatite. In many places the apatite exists in well-defined veins of extreme purity, but the general formation of the lodes is a conglomeration, in which predominance alternates between pure apatite and any of the other minerals I have named.

In regard to the origin of these apatites there has been a vast deal of discussion, many geologists attributing it entirely to animal life, and many others to volcanic action. My own examinations of a number of mines in different districts, and at widely varying depths, have led me to entirely reject the latter theory, and none of my investigations have revealed the least trace of anything that would now connect the apatites with organic life. The explanation which I consider the most feasible is that they must result from a process of segregation, similar to that which in many other places has produced orthoclase and quartz.

As Dana says in his "Manual of Geology:" "The ocean is a mineral spring that dates from a period in the earth's history when the vapors first settled on the cooling crust. All the materials that were at all soluble, and that the conflict of hot rocks and hot waters could have made so, were at first present in it, and an excess of both phosphate and carbonate of lime continued to characterize it after the Paleozoic era had begun, as is learned from the abundance of *Lingulae* and other phosphatic shells."

We all know that the *Lingulae* differ from most other species of shell-fish in the essential fact that the shell closely resembles the bones of vertebrate animals in the respect that it is mainly composed of phosphate of lime. If the sands, clays and marls, deposited from the Lower Silurian seas, therefore, contained notable quantities of these phosphate shells, it is easy to explain that the phosphate would have been dissolved out of them by the excess of carbonic acid in the waters. As the seas became gradually more and more concentrated, they lost their solvent powers, and the phosphate of lime was precipitated. Finally the seas dried up altogether and their deposited beds were metamorphosed into gneissic rocks, pyroxene, etc. This process of metamorphism naturally involved the segregation of the phosphate, and their subsequent subjection to immense heat and pressure finally caused them to assume the crystalline form.

As would naturally be concluded from the very erratic and irregular manner in which this crystallization occurred, the Canadian mining operations are conducted either in immense open quarries, or by means of deep shafts sunk on the dip of the pyroxenite veins at an average angle of 55°, the indications of apatite being sometimes exceedingly small at the surface. Even when the surface "show" is extensive, it, as a rule, soon assumes the form either of small and scattered pockets in the country rock, or of mere strings no thicker than a sheet of paper. If these "stringers" are persistently followed in depth, however, they frequently lead into enormous pockets or "bonanzas" of pure apatite which in some cases have yielded many thousand tons, and have then gradually pinched out again and given way to mica, or feldspar, or pyroxene.

Despite this pinching out, the small indication or "stringer" of apatite has never entirely disappeared, and I know of a number of abandoned mines in which it might still be followed with every possibility of the phosphate again becoming the preponderating mass. Although this kind of mining calls for the generous use of capital and the development of much intelligent enterprise, the persistency of apatite in the vein matter is probably one of the most interesting and encouraging facts connected with the phosphate mining of Canada. It is true that it proves the occurrence of the apatite to be essentially pockety and very deceptive, but it also proves it to be quite unvaried in its geological characteristics. The so-called "lodes" are all of the same mixed-up quality; they may consequently all be mined by the same method; and the quantity of phosphate produced from any one of them is directly in proportion to the total amount of all varieties of rock removed.

In my own experience, the average yield from a good lode in a productive mine and with the best practice, seldom exceeds ten per cent. of the total rock removed, and this is very appreciably reduced by the custom of subjecting the apatite to an expensive handling process, known as "cobbing." This "cobbing" is performed by boys, who take up and examine, on a table or bench, each piece of phosphate that comes from the mine and knock away from it any adhering foreign rock with a small hammer. The apatite being extremely brittle, a great deal of it is thus constantly lost and consigned to the refuse dumps.

Very few, if any, of the Canadian phosphate enterprises have ever paid any dividends on their capital, nor, as I have long labored to point out, can they ever expect to do so while they are so exclusively devoted to the production of the very highest grade ores, and so dependent on the European market for the sale of their output.

If they could create a market for their lower qualities, which, while the cost of transportation would render them unfit for sale in England or Germany, are just what is required for the manufacture of fertilizers for home consumption, the position of the Canadian miners would be at once ameliorated. It would certainly be wiser policy for them to dispense with all their present expensive processes of hand selection and cobbing, and to rest content with such an assortment at the quarry-side as would insure an average grade of, say, about sixty per cent. of phosphate. The proportion of this quality to the total vein matter removed, would be about double that of the pure apatite which is now almost solely sought after, or to put it in other words, instead of ten, their output could be placed at nearly twenty per cent. without increase of cost.

The expense of handling it at the mine, however, is not the only impediment to the greater development of the apatite industry in Canada; another, and very serious obstacle, is the comparative inaccessibility of the deposits. One or two of the most important companies have gone to the expense of constructing shutes or inclined railroads for the carriage of their product to the river's banks, but by far the greater portion of it is at present rolled in wagons or sleighs during the winter, over very indifferent roads, generally leading to a rough storehouse, provided with a weighing shed and a Howe's scale. At this point different compartments or bins receive the phosphate according to its grade or quality, and a series of tramways connect the stored heaps with inclined shutes. From these shutes the material is loaded directly into scows or barges when the rivers are navigable during the summer months.

I have made a most careful and complete investigation into the total average cost of mining and delivering the high grade apatite at the port of Montreal, and find that it may be fairly stated at about $14. The average selling price for material containing eighty per cent. of bone phosphate delivered in Europe is $16 per gross ton. The margin left to cover the cost of ocean freight, insurance and broker's commissions, and to pay a profit on the capital and labor, is consequently $2 per ton.

TABLE SHOWING THE YEARLY EXPORTS AND VALUES OF CANADIAN PHOSPHATES.

Year.	*Quantity, Tons.*	*Value, Dollars.*
1877	2,823	47,084
1878	10,743	208,109
1879	8,446	122,035
1880	13,060	190,086
1881	11,968	218,456
1882	17,153	338,357
1883	19,716	427,668
1884	21,709	424,240
1885	28,969	495,693
1886	20,440	343,007
1887	23,152	433,217
1888	18,776	298,609
1889	29,987	394,768
1890	22,000	330,000
1891	25,000	400,000
1892	8,000	120,000

Turning now to the period known as

THE MESOZOIC AND CENOZOIC AGES,

we find that amorphous "rock" and "nodular" phosphates of lime occur in beds or pockets of varying importance as to area and depth, in the upper cretaceous and tertiary systems throughout the world. The chief centres of production for these varieties, outside of the United States, and the average quantities produced in each are as follows:

	Tons.
Germany (Devonian Dolomites)	35,000
Belgium (in grey chalks of Liège, Ciply and Mons)	300,000
France (Greensands, grey chalks and Jurassic limestone)	500,000
England (Upper and Lower Greensands)	20,000
Russia (White chalk and Greensands)	100,000
West Indies (Tertiary limestones)	50,000
Algeria (Tertiary limestones)	5,000

TYPICAL ANALYSIS OF THE PRINCIPAL AMORPHOUS PHOSPHATE ROCK AND NODULES.

	Navassa.	*Aruba.*	*Curacoa.*	*Algeria.*	*German.*
Moisture	5·73	1·53	0·75	4·50	1·27
Water of combination	4·93	6·03	1·07	2·10	2·17
Phosphoric acid	31·69	36·00	39·62	32·50	29·99
Lime	38·00	47·06	50·04	41·80	42·20
Carbonic acid	2·40	2·30	7·55	1·90	4·15
Oxide of iron	4·25	2·05	traces	1·47	5·15
Alumina	8·81	1·20	0·45		0·12
Sulphuric acid	1·10		traces	traces	traces
Fluorine		1·72	traces	1·25	1·71
Insoluble siliceous matters, etc.	3·09	2.11	0·52	14·48	13·24
	100·00	100·00	100·00	100·00	100·00
Equal to tricalcic phosphate	69·85	69·75	83·37	70·85	65·40

	Ardennes, France.	*Somme, France.*	*Belgian (average) calcined.*	*Russian coprolites.*	*Cambridge coprolites.*
Moisture	5·20	2·00	0·25	5·10	1.24
Water of combination		1·02			1·24
Phosphoric acid	23·45	35·70	20 59	27·48	26·85
Lime	40·80	51·20	52·50	43·00	42·96
Carbonic acid	4·83	4·10	5·55	4·60	7·06
Oxide of iron	2·97	1·40	5·47	3·40	7·16
Alumina	2·15	0·70	7.01	1·09	3·01
Sulphuric acid	1·30	0·76		1·04	0·76
Fluorine	0·94	1·92		0·47	1·15
Insoluble siliceous matters, etc.	18·68	1·20	4·35	13 82	10·41
	100·00	100·00	100·00	100·00	100·00
Equal to tricalcic phosphate	51·22	78·50	45·30	59 97	58·53

All these phosphates are now used up in the countries which produce them, with the exception of the Belgian and those from the West Indies and Algeria, which are chiefly exported to the United Kingdom, France and Germany, and sold at an average price of from $10 to $11 per ton delivered at the centres of consumption. None of them can compare in importance, however with the phosphates of the United States, which all occur in the Tertiary formation, the strata of which may be broadly said to hug the coast of the

Atlantic Ocean, and the Gulf of Mexico from New Jersey to Texas, and to embrace within its area the most extensive marl beds in the world. Phosphate quarries or mines, of more or less commercial value, have been located and worked in Virginia, North and South Carolina, Alabama, Tennessee, Georgia and Florida, and there is no geological reason why the material should not be found in large quantities in other states. For the present however, the only sources that are being largely exploited are the vast beds of South Carolina and Florida, and these are sufficiently extensive to meet all calls that are likely to be made upon them for an indefinite period.

Dealing first with the deposits of South Carolina we find that the geological formation of the phosphate belt is made up of quarternary sands and clays overlying beds of Eocene marls with the phosphate nodules distributed over their surface or mixed up indiscriminately with them. The total area covered by the belt is seventy miles long by thirty miles broad; the richest and most accessible portion being in the immediate neighborhood of Charleston.

Whether the deposit is, or is not, continuous over the whole of this zone, is open to question, but it certainly varies considerably in depth and thickness. In many places it is three feet thick and crops out at the surface, whereas in others it dwindles down to a few inches, or is found at depths varying from three feet to twenty feet. These two conditions, thickness of deposit and depth of strata, taken together with the richness of the material in phosphoric acid, are the chief points for consideration in the economic working of both the river and the land beds on an industrial scale.

The two kinds of deposits, the "River" and the "Land," are both of practically the same chemical description, and both have been worked extensively and are of great commercial value; that from the river being raised and washed from all adhering impurities in one and the same operation by means of machinery.

The rock and nodules occur in very irregular masses of extremely hard conglomerate of variegated color, weighing from less than half an ounce to more than a ton. The mean specific gravity of the material is 2·40, and it is bored in all directions by very small holes. These holes are the work of innumerable *crustacea*, and are now filled with sands and clays of the overlying strata. Sometimes the rock is quite smooth or even glazed, as if worn by water; at others, it is rough and jagged.

Interspersed between the nodules and lumps of conglomerate are the fossilized remains of various species of fish and some animals, chiefly belonging to the Eocene, Pliocene or post Pliocene ages.

CHEMICAL COMPOSITION OF SOUTH CAROLINA PHOSPHATE.

	River Rock.	*Land Rock.*
Loss on ignition	7·01	8·00
Phosphate of lime	59·02	58·63
Carbonate of lime	5·30	8·68
Carbonate of magnesia	0·76	0·84
Fluoride of lime	5·01	4·05
Oxides of iron and alumina	2·93	5·30
Sandy siliceous matters	15·24	13·70
Loss and undetermined	·73	·80

Before the South Carolina phosphate can be made available for industrial purposes, it passes through three distinct and successive operations, which I have minutely described in my book on the "Phosphates of America." Resuming them briefly, they are:

(1) Dredging or mining.

(2) Washing to free it from sand or other impurities.

(3) Kilning to free it from moisture.

The dredging machines are used to most advantage in about twelve feet of water, and are specially constructed for the work with claws and scoops capable of raising immense weights. An ordinary day's work under favorable circumstances, lifts about 100 tons of rock. The rock having been gathered into dippers or buckets, propelled by steam, is emptied on a grating or conical washer, and freed from mud by means of heavy streams of water. Marl, sandstone or oyster shells are then easily detected and thrown aside. Thus partially cleaned, it passes on to a crusher and then to a second washer, where the remaining impurities are separated. The washing apparatus consists of either upright and caldron-shaped, or shaft washers, which discharge the washed rock upon lighters for transportation to the drying-sheds, where it is heaped upon and around a system of perforated iron pipes. The hot air blown through these pipes escapes through the perforations, and thoroughly dries the rock in a few days.

The dried rock is loaded directly into the holds of the vessels by dumping-cars, which are loaded in the drying-sheds from large iron buckets hoisted by steam-power.

The "land" mining, consists in first laying off long trenches and removing the overburden of sands and clays. The phosphate stratum is then removed by picks and shovels and thrown up on the bank, whence it is taken by barrows or cars to be crushed, washed and dried.

The "single-screw" washer is the one most generally used, and it consists of four half-circular boxes resting in a frame on an incline of eighteen inches, and twenty-five feet in length. These boxes are cased with iron. In each box is an octagonal shaft, also cased with iron, and having on each face, teeth or blades set at such an angle to the shaft as to form a spiral screw, with a twist of one foot in six feet. Over each box or washer are strong cylindrical crushers or breakers armed with steel teeth, acting against an iron plate and set about four inches from it. The nodules of rock are dumped through these breakers and broken to a uniform size of four-inch cubes. The rock is then agitated by these bladed shafts, which make about eighteen revolutions per minute, and are submerged in water contained in the tub or box, and is forced forward and up the incline against a heavy stream of water entering at the upper end of the washer-box, and empties itself through an overflow at the end. The abrasion of one piece of rock against another in its passage through the box, rids it completely of all foreign matter, such as mud, etc.

From this overflow it falls upon screens, set one above the other, the first screen having about half-inch meshes, and the lower screen about quarter-inch meshes. From this lower screen the fine rock falls upon an oscillating screen still lower, which serves to rinse it very thoroughly, as a flow of water passes continuously over all the screens.

Finally, the phosphate falls upon an elevated platform, and is thence taken to the sheds or storehouses. The water used is drawn directly from the river and forced up into large troughs by means of heavy pumps, both steam and centrifugal. The washers are considerably elevated for the purpose of getting rid of the *débris*, which is carried off by means of large troughs. The loss by abrasion and clay adhering to the rock varies from fifty to sixty per cent. The capacity of each washer is from forty to fity tons of clean rock in ten hours.

[*To be continued.*]

AËRIAL NAVIGATION.

By A. F. Zahm, Johns Hopkins University.*

[*Concluded from p. 287.*]

Mr. Phillips flying-machine is in some respects no less wonderful than that of Mr. Maxim. Though of small dimensions and weighing in its entirety but 330 pounds, it is yet very efficient and has flown 2,000 feet at a speed of forty miles an hour. Its distinguishing feature is the aëroplane, or sustaining surface, which looks like a Venetian blind eight feet high and twenty-two feet wide, composed of thin slats set horizontally. The slats are one and one-half inches wide, twenty-two feet long and placed two inches apart. The cross-section of the slats is said to resemble the cross-section of the wing of an albatross, and has been adopted after long experiment as offering the maximum support for a minimum resistance. This arrangement has been found to support three pounds per square foot when the slats were all but horizontal and Mr. Phillips expects to reduce their number so that they will be obliged to carry five pounds per square foot of sustaining surface. We may notice that if the Maxim machine were to fall vertically from any height in mid-air its final velocity would be equal to that of a stone falling three feet; whereas the Phillips machine would fall with a fatal velocity in a vertical line. This, however, is not offered as an objection, because the Phillips aëroplane could quickly acquire a forward movement, and thus finding abundant support it could settle slowly to the ground. The propeller of the Phillips machine is a single screw six feet in diameter and of eight feet pitch, which, when rotated at 400 revolutions per minute, exerts a dead pull of seventy-five pounds. Its motor consists of a cylindrical phosphor-bronze boiler twelve inches in diameter and sixteen inches long, furnished with tubes $\frac{3}{4}$ inch outside diameter, and of a compound engine having cylinders $1\frac{3}{4}$ inches and $3\frac{5}{8}$ inches in diameter respectively, with a 6 inch stroke, and fitted with ordinary slide-valves. Quite full descriptions of this machine and its performances may be found in several issues of the London *Times* and of *Engineering* for March, May, and later months of 1893.

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* A lecture delivered before the Franklin Institute, January 5, 1894.

The various flying-machines devised by Mr. Hargrave are sufficiently explained by the photographs which he has sent to the Aëronautical Congress, and which I have brought with me for your inspection. It will be noticed that he employs a pair of flappers to propel his machine instead of the pair of screws used by Maxim. It may be said that Mr. Hargrave began his experiments with very small paper models, using rubber bands for his motive power. After a large number of these had proved successful, he constructed others operated by compressed air, and quite recently he has substituted a steam motor which will operate for a much longer period. He is thus advancing from small, cheap models to a practicable machine, while Mr. Maxim is approaching from the other extreme. Mr. Maxim's resolution to build a new machine of one hundred horse-power would indicate that there are some special advantages in using a machine of moderate size.

Mr. Hargrave seems to have found a satisfactory motor in his simple boiler and engine, and is now studying the question of equilibrium. His cellular kites, shown in the photographs, were designed with that view and were reported to fly with remarkable steadiness even without tails. It will be observed that these kites consist each of a pair of compound aëroplanes, and, if provided with a screw and motor, might be expected to fly with steadiness and stability. It seems to me that these kites deserve the careful attention of aviators in as much as they are rigid mechanical constructions, yet seem to possess most of the requirements of automatic equilibrium and efficient support. Mr. Hargrave directs our special attention to his mistakes and failures, thinking that they may perhaps be as instructive as his successes. He has given quite liberal and complete details of all these in the *Proceedings of Royal Society of New South Wales.* He expresses the generous view that all inventors should publish their results immediately so as to hasten the day of successful flight, which, he says, is "dead sure to come." He adds that we should be animated with the desire of benefiting mankind with these machines and not of advancing the powers of war and destruction.

Many other inventors are at work on similar machines, but as yet we have scant reports of their progress.

We may now notice briefly the three general types of machines which have been designed to accomplish active flight. They are: (1) the bird type, (2) the aëroplane type, (3) the screw type. The bird type has been followed with some success in small models and might be employed in a machine large enough to carry one man, but it seems to possess a fatal property which will prevent its adoption in the larger machines; that is, the moment of inertia of a wing increases as the fifth power of its linear magnitude. While the wing is small, as in the birds, hardly any power is consumed in the changes of momentum due to its reciprocating stroke. The wing, after its down stroke, may actually glide on the air during the upstroke so as to scarcely tax the elevator muscles at all. But if the wing were an artificial one of great size and mass, the air would not support it during the up stroke, and, consequently, the kinetic energy which it possessed at the end of the down stroke would be lost. This latter might be communicated to an elastic spring and so recovered to some extent, but such a thing has not yet been accomplished. The whole mechanism of the bird's wing seems to be too complicated for imitation on a large scale, and besides, as it consists of two distinct parts, a propeller and a sustainer, it seems but natural and proper to separate them if the nature of our motors calls for it. This would lead us to the aëroplane.

The aëroplane with its screws may be regarded as a simplified pair of wings whose bases remain fixed supporting planes, while their remaining parts exert a forward pull. This arrangement offers the advantages of a circular motion for the propeller, and of fixedness for the sustaining planes which may thus be made very large. It accordingly seems to be most extensively adopted by inventors.

The screw type of flying-machine offers the distinct advantage of being able to rise directly from the earth from a state of rest and of maintaining exceptional stability in the air. It has, therefore, been proposed as the proper form for man's earlier attempts, especially since it may be transformed into the more efficient aëroplane type by the gradual addition of sustaining surfaces to the body of the machine.

If the flying-machine is not lifted into the air from a state of rest, some special provision will have to be made for getting it under way and alighting safely. I do not think, however, that this objection will prove a very puzzling one. If we can afford to fly at all we can doubtless afford to have smooth starting places, or depots, where a short initial run may be made to acquire sufficient speed to launch into the air. This could not be practised in extensive rambles or explorations, it is true, but neither could the special fuel required for the motor be found in such extended excursions.

The problem of the stability and steadiness of flying-machines seems to me to be comparatively easy of solution for calm weather, but very difficult for windy weather. If the wind blew in a uniform stream it might be encountered with some confidence, but it blows in gusts of varying velocity, and, near obstructions, it is disturbed with eddies and whirls. As I shall show by some records obtained from a special recording anemoscope, to be described in the May issue of *Aëronautics*, the wind, even in the open fields, may blow in an irregular, wavy manner. As a consequence the flying-machine will be constantly exposed to being tossed like a boat at sea. This it might endure to a limited extent; but if it should receive a sudden side gust or encounter a disturbance such that one wing should be lifted while the other was blown downward, it might be completely overturned. The machine might automatically recover its poise, but the jostling due to such a mishap would doubtless be objectionable to the passengers, if not injurious to the motor. In such irregular gusts and eddies the balloon would probably be much safer and steadier than any form of flying-machine.

I may say that the problem of the stability of the flying-machine is now the most serious one calling for solution. What little has been written on the subject is largely of a speculative nature. In my own experiments with aëroplanes, which were limited to small models launched freely in the air without propelling mechanism, I was led to believe that, for ordinary winds, the stability of a flying-machine might approximate to that of a boat on the water; but for the more violent gusts, especially for those near obstructions, the flying-machine would behave like a frail boat on a torrent, or on the fierce breakers of the seashore. I concluded, therefore, that the flying-machine might weather a gale till it became too furious, then, like the birds, nestle down in some place of shelter. It is assuring to observe that Mr. Maxim has no apprehensions for the stability of his machine in windy weather.

PASSIVE AVIATION.

At the Aëronautic Conference last summer, no less than seven or eight papers were presented describing the phenomena of soaring and suggesting devices for imitating the performance. Dr. Langley presented an elaborate paper on "The Internal Work of the Wind," in which he declared that, with a soaring machine, man might circumnavigate the globe without motive power, if he but knew how to avail himself of the resources of the atmosphere. Dr. Thayer, of Boston, told us that he had seen a sea-gull soar from Queenstown to New York in the teeth of a forty-mile gale, and that, in spite of the opposing wind, it could at will glide ahead of the swift ship without effort. M. Monillard, of Egypt, who has been watching the birds for forty years, informed us that he had actually succeeded in soaring a little bit himself, and that if he were not so old and crippled, he would venture still further.

One of the most successful students of soaring, as of aviation in general, is Herr Lillienthal, of Berlin.

Equipped with a pair of long wings, he has been practising the art of gliding with systematic regularity during the past two summers. "Almost every Sunday," he tells us, "and sometimes on weekdays, I went out to practise on the hill between Grosskreutz and Werder. A mechanic, Herr Hugo Eulitz, the maker of my apparatus, went with me, and each practised alternately while the other rested. Thus we obtained dexterity in gliding down on the air and in landing at the foot of the hill without mishap. Herr Kassner, of the Meteorological Institute, was so kind as to photograph me in the air, and has thus enabled me to exhibit to the members of the German society how I sailed right over the head of the miller of Derwitz, in whose barn I stored my apparatus."

I may add a word as to the dimensions of this apparatus and the mode of using it. The wings were made of willow covered with sheeting-fabric; they measured some thirty feet from tip to tip and weighed 39·6 pounds. Taking them in his hands as shown, and selecting a hill which sloped towards the wind, Herr Lillienthal ran along its top, sprang into the air and coasted downward, as a boy does on a sleigh, to a distance of sixty-five to eighty-two feet.

These are but preliminary studies in the art of steering and balancing. If they do not lead to the actual achievement of soaring they may at least impart such skill and confidence in manipulating an aëroplane as to enable him, when motor and propeller have been added, to make his first active flights without serious risk. The importance to the art of flying of such exercises in aërial coasting seem to be so great that one might wish to see them become a popular pastime. If the sport of coasting on the air should only prove as attractive as that of coasting on the hill-side, the talent now spent in other difficult feats of balancing might advance the art of steering in the air, possibly even of soaring.

I will not venture to offer a theory of soaring, that is to say of that gliding performance by which the bird increases its total energy without active muscular effort, for every one has a theory of his own; but I will make two statements which seem to be axiomatic.* These are: (1) that a bird cannot soar in a perfect calm; (2) that a bird cannot soar in an even wind, that is in a horizontal wind of uniform velocity and direction. This latter statement is not generally admitted, even by eminent writers on aviation; yet it seems all but axiomatic and has the sanction of excellent authority.

The problem of soaring on outstretched, motionless wings by the sole energy of the treacherous and inconstant wind is surely one of the most fascinating that has ever presented itself to the mechanical inventor. Whether viewed as an instance of the supremacy of intelligence over the blind forces, or as the perfection of the grace and glory of motion, or as a thing of exquisite uses and delights, this Godlike act seems to me to be one of the most marvellous and amazing performances of all animated nature. To think of riding from earth to sky without effort, of pitching through all heights and depths, of careering among the splendors of the immensity from the rising to the setting sun! No wonder there have been enthusiasts.

Everybody has watched these evolutions of the birds; everybody loves to watch them; but so extraordinary do they seem that many observers mistrust the evidence of their sight and deny their possibility. Yet the feat has been observed by men who have made it their favorite study, who have followed the birds again and again with large telescopes, and who assure us that the wings remain outstretched and motionless, that the birds ride by sheer instinctive skill upon the fickle wind.

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* See *Aëronautics* for June, 1893.

I myself have observed such performances under every conceivable circumstance, in the mountains and on the plains, and so close that I could observe every movement—for it has been with me a passion and an inspiration to watch the birds, and I am convinced from long observation that they can, at times, rise from near the earth to the sky without once beating their wings, without the slightest rowing, without any muscular movement more than that of steering.

CONCLUSION.

To one who yearns for the extraordinary in engineering there is something delicious in the assurance of our modern aërial navigators—they are so entirely confidant. It is true there have been from the dawn of time enthusiasts who have looked for the immediate accomplishment of human flight, even at their own hands; but they were the dreamers, not the scientists of their day. We can now name scores of men who have won distinction in both theoretic and applied science, who, having examined the conditions of this problem, express an unwavering confidence in its near solution. This is especially true of those who have studied the matter most profoundly. Prof. Langley, at the conclusion of his admirable researches in aërodynamics, thus writes: "I wish to put on record my belief that the time has come for these questions to engage the serious attention, not only of engineers, but of all interested in the possibly near solution of a problem, one of the most important in its consequences of any which has ever presented itself in mechanics; for this solution, it is here shown, cannot longer be considered beyond our capacity to reach." And concluding an article in the *Century*, September, 1891, he expresses himself in this unequivocal sentence: "Progress is rapid now, especially in invention, and it is possible—it seems to me even probable—that before the century closes we shall see this universal road of the all-embracing air, which recognizes none of man's boundaries, travelled in every direction, with an effect on some of the conditions of our existence which will mark this among all the wonders the century has seen." A month later, Mr. Maxim, after discussing the requirements of flight and the manner in which it may be compassed, declares: "The motor has been found, its power has been tested, and its weight is known. It would, therefore, appear that we are within measurable distance of a machine for successfully navigating the air; and I believe it is certain to come whether I succeed or not." Mr. Chanute, who may be very aptly styled the critical historian of aviation, and who, as late as 1890, still expressed a lingering uncertainty as to the prospect of aërial travel, has, within the past two years, written an exhaustive account of man's attempt to fly in order to prepare his countrymen for the coming events.

Perhaps the most significant indication of the approaching importance of aërial navigation may be observed in the serious attention devoted to it by the European powers, the costly investigations they have instituted and the profound secrecy they have maintained. If we are to believe the frequent rumors of foreign newspapers and the surmises of semi-political writers, both the French and German governments are prepared to body forth at any time the unalluring vision of Tennyson.

What may be the future applications of aëronautic craft beyond those of observation and warfare can be but vaguely foreseen. While such craft give no promise of ever carrying the great burdens of the world, they may perform many of the special offices of transportation with efficiency. The flying-machines, especially, which, for burdens of one to a score of passengers, can doubtless be operated without great expense, since there is no cost for roadway, may not improbably give rise to an aërial livery that will be as convenient and useful as it will be delightful. One would judge from the experiments thus far made, that such machines could be manufactured as cheaply as our locomotives, operated as cheaply, housed and repaired almost as easily, driven as fast, and hundreds of miles without a halt.

It were vain for us to speculate on the eventualities o the conquest of the air, for they were incalculable. Let us but hope that the spirit of peace may vanquish the spirit of destruction, that she may body forth only the fairer vision of the poet, and realize in one victorious sweep the golden time of the prophecy:

> "When the war-drum throbbed no longer, and the battle flags were furled,
> "In the parliament of man, the federation of the world."

[The lecture was profusely illustrated with the aid of lantern slides.]

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from p. 305.*]

We are now prepared to consider what is the education which a young man needs to fit him for the profession of engineering whatever be the special line of engineering which he proposes to follow. And, before discussing on the details of what he ought to study, let us consider what it is that we desire to accomplish by giving him an engineering education. Naturally, we wish, as far as any education can accomplish it, to put him in the best condition to meet and grapple with the duties, the problems, and the responsibilities of his profession, as they arise.

There are two things which are absolutely necessary to make a successful engineer; first, a knowledge of scientific principles and of the experience of the past; and second, his own experience. The last cannot be given in a school, and each one must gain it for himself in his practice.

But the greater his familiarity with scientific principles and the experience of the past, the more able will he be to advance in his profession, and to be trusted to assume responsibility; indeed, if a man is ignorant of certain details and knows he is ignorant, he can—and if he is the right kind of a man, he will—take pains to learn them, if they bear on the work he has in hand; but if he is ignorant of scientific principles it is very likely that he does not know he is ignorant, or, if by good luck he becomes aware of the fact, it is next to impossible for him to devote the time and study necessary to correct his ignorance while his mind is busy with his daily work.

Moreover, a man who is not familiar with the scientific principles which concern his work is not a safe man to trust with responsibility; for scientific principles are merely the laws of nature, as far as known, as shown by the experience of the past.

Hence it is that the first and most important thing to be done for the student is to give him a thorough drill in the scientific principles, which find their application in his profession. It is in the school that this knowledge may best be acquired since it is only with great difficulty that principles can be mastered after the student begins practice, and then as a rule but very imperfectly; and this view is borne out by those engineers who have been successful, and who have had to acquire their knowledge of scientific principles little by little, and, as best they could, during the practice of their profession. Too much cannot be said by way of insisting that a thorough mastery of such scientific principles far outweighs in importance anything else that can be done for the student; and this is so true, that it is a decided mistake to neglect it in order to impart to him greater skill in such processes as will probably engage his attention the first year after he goes to work, as, for instance, to make him a skilful surveyor, a finished machinist, or an elegant draughtsman. Greater skill can far more easily be acquired after he goes to work, than can scientific principles, and if this mistake is made the consequences will probably pursue him throughout his professional life.

The two fundamental sciences upon which the scientific principles of engineering are especially dependent are mathematics and physics, and no proper course in engineering can be arranged without insisting upon these as fundamentals.

Let us begin with the subject of pure mathematics, and consider what portions should be studied, how they should be studied, or rather how they should be known, and of what service they are to the engineer after they have been mastered; bearing in mind that, in accordance with the opinions already expressed the course of study should be laid out with direct reference to the needs of the engineer; and that when it is so laid out, it will, by the very fact that it leads to a definite end, subserve best the purpose of true education, and hence of developing the powers of the mind. Probably the best definition of mathematics is that given by Prof. Benjamin Pierce, who defined it as "the science of drawing necessary conclusions." This definition, of course, includes formal logic, and hence embraces more than is ordinarily understood by mathemathics. We may assert, however, that the only function of mathematics is to draw necessary conclusions from the assumed data. Mathematics has nothing whatever to do with the correctness or incorrectness of the data. If these are correct, the conclusions deduced by mathematics will also be correct, whereas, if the data are false, the conclusions deduced by mathematics will be false.

Thus, if we require the sum of a certain set of numbers, the process of addition will give the correct result, provided the numbers added are the right ones; but if the numbers added are not the right ones, the result of the addition will not be the one desired. Indeed, we might compare pure mathematics to a mill, it will only produce good meal when the corn furnished to it to grind is of good quality; and if the corn is poor the meal produced will be poor. With the selection of the corn which it is to grind, the mill has nothing to do.

No natural law can be discovered or proved by mathematics alone; the discovery or proof of natural law requires experiment and observation in all cases.

Just as arithmetic is a means of making calculations of certain kinds, so there are other kinds of calculations that can only be performed by the use of mathematics higher than arithmetic; some kinds require algebra, some geometry, some trigonometry, some descriptive geometry, some analytic geometry, and some the differential and integral calculus; while others yet require higher mathematics. Now, inasmuch as every one can easily understand the necessity of arithmetic for the purpose of making the calculations, and drawing the conclusions which come within its province; so, it follows that the engineer should have a thorough working knowledge of whatever portions of pure mathematics he needs, to make the calculations that are liable to arise in his work, and also to draw the necessary conclusions which concern the engineering and scientific subjects with which he must deal in his profession. This latter is an all-important matter; for, if our prospective engineer is to be fit to assume responsibility at some portion of his career, before he allows himself to use a formula in practice, he ought to know just how it is deduced, and what are the assumptions that were made in deducing it.

The rule-of-thumb engineer ignores this matter, and allows himself to risk the money, the safety, and the lives of his fellow-men by making use of constants and mathematical formulæ found in some hand-book or elsewhere; using these constants and formulæ blindly, without knowing how they were deduced, or whether they have any reasonable foundation to stand on; or, in other cases, contents himself with merely guessing at what should be the dimensions of the various parts of a structure or machine. The natural result of such a course is poor work, and often disaster: and the world is rapidly waking up to this fact, so that important engineering work is being less and less entrusted to these rule-of-thumb engineers.

Now, I may say that knowledge of at least all these subjects mentioned in my communication—through the differential and integral calculus—is necessary for our prospective engineer.

As to descriptive geometry, that is classed by many, not as mathematics, but as a branch of drawing. It is the mathematical work upon which the making of engineering drawings of all sorts is based, and hence I have put it in this list.

So general has the conviction become that the engineer needs some knowledge of the differential and integral calculus, that it is not necessary for me to cite cases where he must use it if he is to perform his work intelligently and not by rule-of-thumb. Differential equations is a subject which is sometimes classed with the differential and integral calculus, and sometimes as a separate subject. It is one that should, if possible, be learned at least to a small extent, though the more that is known about it the better.

As to the special work to be done in each of these subjects, it is a matter of judgment with the one who lays out the course, and I shall not weary you with these details; but I must explain what ought to be the result aimed at, in other words, how the student should know his mathematics.

I might express my idea by saying that he should acquire the ability to use it as a tool, but, when I say that, I mean not merely as a tool for making computations, but also as a tool for drawing necessary conclusions of the kinds that apply to his engineering work; and this last is the feature which is most frequently lacking in the mathematical instruction given to engineering students.

By one method often pursued in teaching mathematics, the student is made to grind through a certain round of operations over and over until he has been so drilled in performing them mechanically that he can *perform* a similar problem. By this method, he is only taught to use it as a tool for making computations.

Another method, often pursued, is to exercise the student's ingenuity in performing a variety of (sometimes puzzling) problems which are of purely abstract interest, and are not planned in such a way as to bear upon the class of problems liable to arise in engineering work or study. This course probably tends to make the student do more thinking, but does not direct his thinking in the channel most useful for the prospective engineer. To accomplish the desired object in the teaching of mathematics, it is, of course, necessary that the teacher should be able to grasp the requirements of the engineering courses, and should know the special kind of use that the prospective engineer will have for his mathematics later in life.

Another important matter, the accomplishment of which concerns the treatment of the subjects of a mathematical nature that follow in his course, rather than the treatment of the pure mathematics itself (though the mathematical department can help in this matter), is that the student should be taught to distinguish between the mathematics of the work, and the assumptions made at the beginning, or in the course of it, respecting the proposition he is dealing with. The student is prone to fail to draw this distinction, and to consider things that are pure assumptions —sometimes based on facts and sometimes not, sometimes true under one set of conditions and not under others—as being the deductions of pure mathematics, and hence, as conclusively proved and applicable under all conditions. Such a course is fraught with danger for the student who does not understand and grasp what are the conditions of the problem he is dealing with, and who is therefore liable to apply the result to cases when the conditions are entirely different, and where, consequently, the result is not at all applicable. He is also prone to consider as demonstrated, things which are not, but which are only proved to hold, provided certain assumptions are true; whether these assumptions are true or not being left for experiment to determine. In cases where certain approximations are made which are justifiable under certain (perhaps the ordinary) conditions, the student who does not observe what these conditions are, is tempted to use the approximations when they do not hold, and hence to deduce wrong results.

For example, I have seen a long mathematical (so-called) demonstration claiming to prove something which was manifestly absurd, wherein the mathematical work was all right, except that a certain quantity was neglected which, under ordinary circumstances, was small, but which in this particular case was infinity. To the student who had not the grasp on his mathematics which would enable him to see what had been done, it would have appeared that the absurdity had been proved.

Perhaps I might sum up a part of the above by saying that the student should be taught to think, and that the attempt to teach him to think should begin as early as possible in his course, and be kept up throughout. It is much easier for the average student to learn a lesson to recite by rote even if it contains a lot of formulæ, than it is to do a little solid thinking himself, and yet the more we can make him think the more successful in every way will he be.

It may be well to mention in connection herewith another matter of great importance, and which is too often not properly considered by some of those who teach the subsequent engineering studies.

The teachers I have in mind have had a training in pure mathematics which was not laid out with any reference to a subsequent engineering course, but such as had become customary in the colleges, with a view to general training only. In such a course, certain equations, certain courses of abstract reasoning, certain steps have become, as it were, crystallized; and these teachers adapt their engineering work to these crystallized forms. Thus, if a certain problem is to be attacked which could be regarded mathematically as a special case of some more general problem, they would always approach it through the general case, whereas, though this general case might logically precede it if we confined our thoughts to the calculation, its generalities might be of such a nature as to have nothing to do with any case that the engineer would ever have to deal with.

Now a teacher who takes this view, requires his students to perform a large mass of purely mathematical work, for no purpose, and, worse than that, he draws away the attention of the student from a proper consideration of the assumptions, of the data and of the scientific principles involved in his problem, whereas these should be the matters uppermost in his mind, while his mathematics should be a tool with which he is thoroughly familiar, and which he can use freely and correctly to draw necessary conclusions in the problems with which he has to deal. In the early days of engineering schools when the science of engineering was not as fully developed as it is to-day, this would naturally be, and was the course taken by the more educated teachers of, and writers on, engineering subjects; and, on the other hand, the large amount of irrelevant mathematics, the paucity of experimentally ascertained facts applicable to engineering work, and the liability of the young man to fail to examine critically the truth or falsity of the assumptions, which were almost hidden under such a mass of mathematical equations, and hence his liability to consider as demonstrated truths things that were subsequently proved by experiment to be untrue; have doubtless been responsible for a large number of the objections that have so often been made to a mathematical training for the engineer; and in many cases where a man speaks against the use of mathematics in engineering, we shall find, if we examine carefully, the spirit rather than the letter of his objections, that what he really objects to is just the erroneous use of mathematics where a man always works out the solutions of his problems with a lot of equations, but does not take pains to examine first the assumptions at the basis of his work. But now that engineering science, and also engineering schools are much more fully developed, this kind of teaching is fast dying out, and with it the purely empirical work and teaching which is the opposite extreme and which is fully as baneful in its results.

Perhaps those of you (if there be any) who teach mathematics may think that the standard I have set is high. I admit that it is, and also that it requires hard work, good judgment, and the qualities of a good and efficient teacher, not only in laying out the course, but even more in teaching the class. Nevertheless, this standard is the one that is needed, and good judgment, and good teaching can at least approach near to it within the time that can be afforded in our engineering courses, even with such previous mathematical preparations as can be obtained to-day by the students before they enter the engineering schools; and as fast as it becomes possible to raise the standards of admission, the standard I have set can be even more fully realized.

The other fundamental science which I have mentioned is physics. It may be defined as that department of natural science which treats of the laws governing the various manifestations of energy (as gravitation, sound, heat, light, electricity, etc).

It deals with natural law as it applies to just those classes of bodies, and substances with which the engineer does his work. Indeed, physics is a very general term, and might be made to include a great many subjects that are usually called by some more special name. For instance, mechanics is sometimes spoken of as a separate science, and sometimes as forming a part of physics, and, moreover, under any definition physics includes a part of mechanics.

Practically, a course in physics is the suitable preparation for a proper understanding of the scientific principles of most of the engineering work with which the student will come in contact. Treating, as it does of the laws of nature, the more thoroughly an engineer knows it, the more successful will he be, and an ignorance of these laws can only result in failure,

Mechanics, light, sound, heat, and electricity, are all matters that concern the profession of the engineer so intimately that he cannot afford to neglect a careful study of their first principles. It is unnecessary for me to say, therefore, that there is no portion of the work usually treated in the best and most thorough courses of general physics but what should be included in the course of our prospective engineer.

Then, a certain amount of work in the physical laboratory is of great importance for the student, for it teaches him how to ask questions of nature, and how to get correct answers; in other words, how to make careful and accurate experiments, and this is a matter that intimately concerns the engineer. It is true that the greater part of his experimental work will have to be performed on a considerably larger scale than that usually carried on in a physical laboratory; but, on the other hand, some of his most important and delicate work involves the doing of just such experimental work as he is taught to carry on in a well organized and well equipped physical laboratory; and also the performance of these physical laboratory experiments is a proper introduction to his later course of experiments on the large scale, drilling him in accuracy and care while working on small amounts of material.

Indeed, I might mention quite a number of experiments which are all-important to the engineer, and in regard to which, it would be difficult to decide whether they should be called physical laboratory or engineering laboratory experiments, since they often have to be performed in both. Thus, the calibration of thermometers is a matter that is properly taught in the former, and yet the engineer who is to do delicate engineering work is liable to have to calibrate his thermometers, or at least to make a careful and accurate comparison with a standard which he or some one else has calibrated. Again, the determination of the mechanical equivalent of heat is a matter of vital importance to the engineer, but the best, and most accurate work thus far upon the subject has been done by Professor Rowland, a physicist, in his physical laboratory.

As a rule, when experiments are to be performed on the large scale they get beyond the possibilities of a physical laboratory. In this category we may place such experimental work as the testing of steam engines and steam boilers, the testing of the strength of materials of construction on a practical scale, etc., but, in order to carry out these tests with proper accuracy we have generally to perform delicate measurements, as, for instance, measurements of temperatures, etc., in the first, and measurements of very small elongations or shortenings in the second case, and consequently have to use the suitable apparatus with the necessary degree of accuracy.

Since we have just been considering mathematics and physics, which may be called general sciences, perhaps a few words should be said in regard to chemistry. I cannot claim for it a similar position of fundamental importance in the engineering part of an engineering course that belongs to mathematics and physics. Nevertheless, a certain amount of chemical knowledge is of great importance to all engineers, but when they have passed this point, although a farther knowledge would be useful, it is not one of the most important things. The chemical composition of fuels, of steels and irons, of cements, of oils, and of other materials is a matter that directly concerns the engineer. It is true that he can usually have his chemical analyses made for him, and generally would better do so; but he must know enough of chemistry to understand the bearing which the chemical composition of his materials have on their use in engineering work. Some knowledge of industrial chemistry is also desirable, so that he shall understand the nature of the processes performed in manufactories in which chemical processes on a large scale are performed.

The instruction in chemistry should, if possible, be given very early in the student's course. In the case of the Massachusetts Institute of Technology, and also, I think, in that of several other schools, both lectures and laboratory work in chemistry are given in the first year, and when this is done the instruction in chemistry fulfils another important function, viz: it introduces the student at the very threshold of his course to a species of scientific work that obliges him to think, and this, in a direction in which, as a rule, he has not been trained in the preparatory schools. Especially is this true of the laboratory work, for, by observing the results of experiments which he himself makes, he must learn how to interpret the replies of nature; and as chemistry, unlike mathematics, is an experimental science, it trains the thinking powers of the student even more than do his algebra, geometry and trigonometry.

[*To be continued.*]

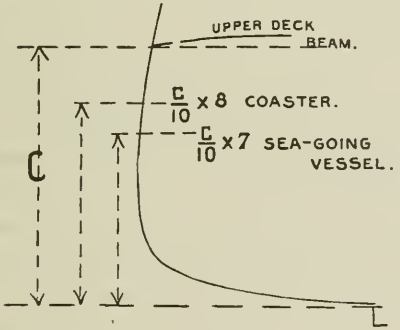
A PRACTICAL AND EASY METHOD FOR DETERMINING OR COMPARING THE FREE-BOARD.*

BY A. BOD, Naval Architect.

Respecting this eminently important question, considered principally from the point of view of habitability, during the period of constant, or, more exactly, nearly constant ratios, the rules were very simple. One which was frequently used in merchant ships was

$$\frac{C}{10} \times 8 \text{ and } \frac{C}{10} \times 7,$$

respectively for coasting and sea-going vessels; C in each case representing the depth.


UPPER DECK
BEAM.
$\frac{C}{10} \times 8$ COASTER.
$\frac{C}{10} \times 7$ SEA-GOING VESSEL.
C
L

These rules were taken only in function of one dimension instead of being made in function of the displacement, but at that time the ships were built nearly with the same ratios between their principal dimensions.

The constant increase, principally in length, of every type of vessel has made these rules useless, and for a while several systems have been heard of, but admitted by few. Some of them are very simple in their application.

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[*] To be read at the stated meeting of the Section of Engineers and Naval Architects, November 28, 1894.

Upon this subject Mr. Dislère gave the following rule:

"Let h designate the height of free-board, p the depth from line of flotation to rabbet, l the length of ship, $\frac{h}{p}$ the ratio between the emerged and immerged parts of hull, which ought to remain between nine-tenths and one, and the ratio $\frac{h}{l}$ between the emerged part and the length of ship ought to remain between one-fifteenth and one-twenty-third.

"In England, the case of the iron-clad *Rodney* is as follows:

$$\frac{h}{p} = 0{\cdot}49$$

and

$$\frac{h}{l} = \tfrac{1}{27}."$$

It is not surprising that with such ratios this ship has not a sufficient habitability when in a rough head sea.

Mr. Dislère says:

"It is not only to prevent the ship from being swept by the water that a high free-board is required for a cruiser, although for diminishing the displacement it was admitted to reduce the free-board. The English committee made this reduction also, in order to decrease the target, and proposed the exclusive adoption of ships with barbettes. But it must not be forgotten that a ship which stays at sea a long time would be efficaciously protected, not only forward and aft, but also by the beam. The height of free-board should be greater when the height of the immerged part is increased and the ship longer."

Mr. Benjamin Martell has formulated a rule which, although proportionate to the volume, varies with the kind of ships to be classified.

He made a difference between a flushed-decked, awning-decked, spar-deck weak, spar-deck strong, full poop, etc., but the expressions in one-tenth or per cent. giving more or less draught, do not seem proportionate to the ship to be regulated, but look like a mean taken from some type, and the result suits the case in question more or less closely.

I think the best way is to have a rule, short and simple if possible, which can be applied to each kind of ship, and not admit weak scantling at any part of the hull.

All awning-decked, spar-decked and other weak construction should be relegated to a coasting navigation.

Now, Lord Brassey's opinions respecting the free-board may be read in the following extract from that invaluable book, the "Naval Annual:"

"Ships with a low free-board are too much under water to be reasonably habitable.

"Steaming to the westward from Berehaven on a summer's night, the fore-deck of the *Devastation* was swept by sheets of foam, while the upper decks of broadside ships were towering high above the waves. That a turret ship of low free-board is the most powerful type for battle will not be disputed, but life on board in a long cruise would be wretched.

"The American monitors were too deficient in free-board to be habitable at sea.

"It would be in long cruises that the defects of the *Polyphemus* would make themselves felt. Even in favorable weather the ordinary swell of the Atlantic breaks on the deck as upon a half-tide rock, compelling the crew to remain below.

"Close and constant confinement under hatches would lead to a rapid deterioration in the physical condition of the men. The one capital defect of the *Polyphemus* would be remedied by building up amidships a superstructure of moderate height.

"Even the *Mercury* is not adapted for steaming against a head sea. She requires a light covering-deck fore and aft, with no bulwarks to hold the sea." (See remark about *Iris*).

"With the sea and wind ahead, or even before the beam, the torpedo boat is swept from end to end; the torpedo boat labors heavily. The great speed in a heavy sea is one of the great defects of the torpedo boat, and must, if the vessel was exposed for a long period to heavy weather, result in considerable damage."* (Extract from Leroy's report.)

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* About the torpedo boat, see p. 390.

I lived for two years in Canada, where, every Saturday afternoon in the summer, and every Sunday before the closing season, I saw the shipping of cattle, and I can assure you that it was pitiful to see the manner of making awning-decks to shelter the hay which is put on board several feet above the railing.

It is a well-known fact that such a ship cannot carry all her cargo without suffering some loss or damage.

Mr. Plimsoll came forward at this time with his system to prevent in some measure the waste of material and the danger to human life. With reference to these matters, if any of my hearers should want more information, they should ask the insurance companies how much they have paid for these risks.

It seems strange to me to see so many ships built with scantlings good only for coasting navigation, running in the upper part of the North Atlantic, where large steamers like those of the Allan Line encountered, from time to time, such rough weather as to necessitate great repairs.

I saw one of these large steamers entering Montreal harbor in a very storm-beaten condition, the chart-room, many boats, etc., having been washed away, the captain fatally injured and several seamen and passengers drowned. All this proves that ships which are not built with scantling strong and well enough connected, and the overloading of whose upper deck with cargo is not prevented, are not fitted for the severe navigation which they must encounter in high latitudes.

It is not necessary to make use of mathematical expressions to see that the increase in length of a ship compels us to put in a greater number of compartments; and supposing, for instance, that for a special trade the bulkheads be placed apart in such a manner that two adjacent compartments can be filled and give a very small change in the trimming, do you believe for this reason that a low free-board would be adapted for this ship, and that, though there might be no fear about the volume of water having free access by the injured part, the ship could be navigated in an easy manner?

For the upper structure and superstructure the ideas expressed in the following paragraph are generally admitted:

"There are vessels with spar-decks, with awning-decks, and with forecastles, poops and houses upon decks, that vary greatly in size and strength. Most steamers have deck erections of some kind; and these add greatly to seaworthiness if they are strongly constructed and well connected to the deck on the side of the ship."

My opinion is that no erection should be straight to a great extent, because the scantlings of these structures are generally light, and if the faces are made round the resistance will be greatly increased. Too often we read of, or see along the wharves, ships which, having encountered a rough sea, have had a house-deck, or chart-house, etc., partly or entirely washed away.*

If we let L represent the length, and W the displacement, it will be enough to give some approximate values both in functions of L and W concerning the flooded parts, in order to see at a glance the great difference which can be produced by one compartment more or less.

In the two types† shown in Nos. 1 and 2 the ratios between the two flooded compartments are the same; the diagrams hereto annexed indicate sufficiently both the location and volume; and the moment will be expressed by

$$\frac{L}{4} \times \frac{W}{4} = \frac{L\,W}{16}$$

indicating both draught and trimming, which vary to a great extent; and by a glance at the similar sketches Nos. 1 and 2, shown further on, it will be easy to understand that these ships would be in very bad condition.

The same criticism will apply to the two types shown in Nos. 3 and 4, in which the difference consists in the value of the expression

$$\frac{L}{3} \times \frac{W}{6} = \frac{L\,W}{18}$$

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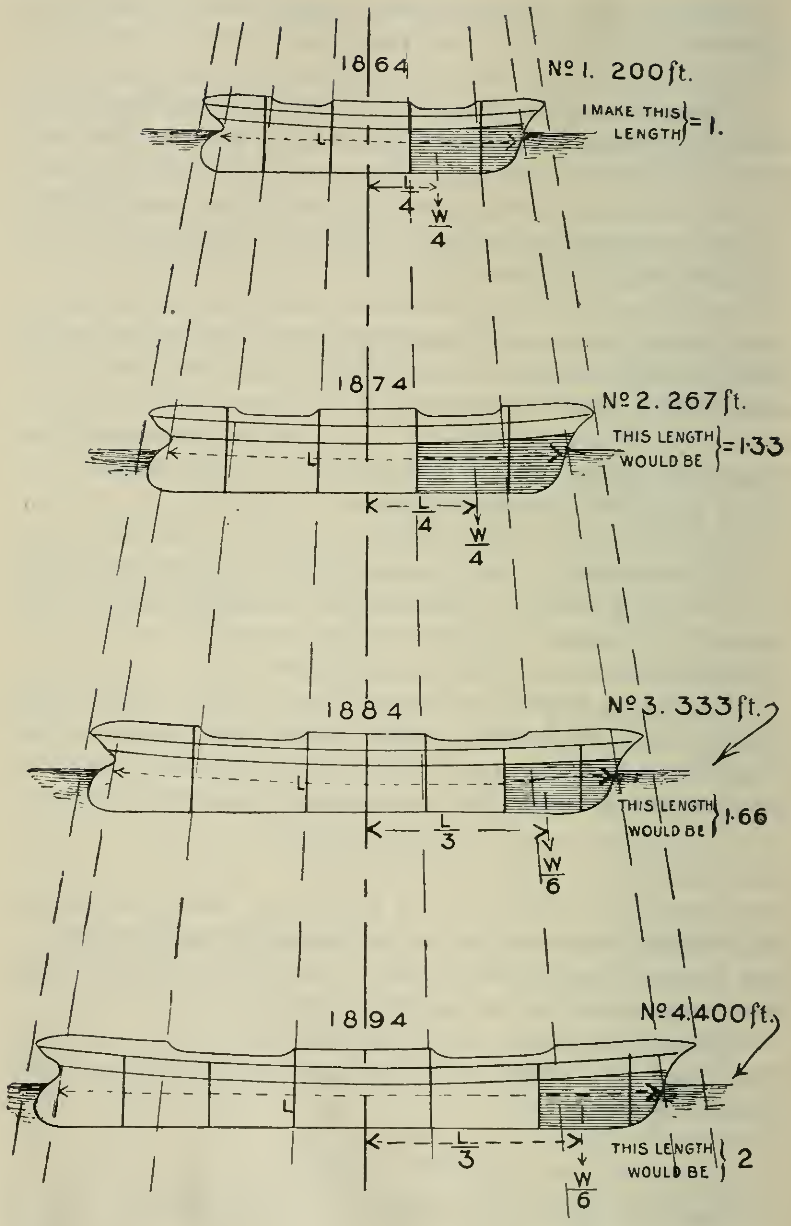
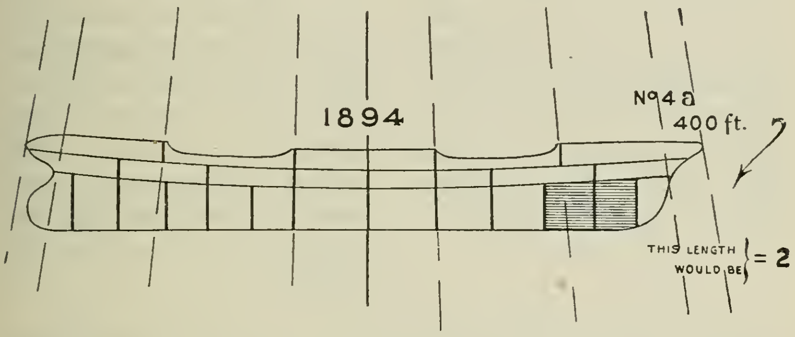
* (Read on p. 378 the terrible accident to the *Pomeranian;* also the remarks on torpedo boats on p. 390.

† The dates and dimensions for the following sketches are given only for comparison. (Read English rules on p. 379.)


1864
Nº 1. 200 ft.
I MAKE THIS LENGTH = 1.
L
L/4
W/4
1874
Nº 2. 267 ft.
THIS LENGTH WOULD BE = 1·33
L
L/4
W/4
1884
Nº 3. 333 ft.
L
L/3
W/6
THIS LENGTH WOULD BE 1·66
1894
Nº 4. 400 ft.
L
L/3
THIS LENGTH WOULD BE 2
W/6

In these cases both draught and trimming do not vary to such an extent as in Nos. 1 and 2, although the free-board would be affected in an important manner. If in this case the ships have not so great a moment in proportion to their displacement, the sketches Nos. 3 and 4, p. 372, show that they also would be in bad condition.

In the case of a tank vessel or vessel fitted for special service, where a great number of bulkheads will be required (see sketch), the draught, trimming and free-board would not be much affected by two flooded compartments.



Now, how should the free-board be regulated to suit every successive increase?

By observation, we know what may be done and what may be avoided in order to have a good habitability, so we may compare the following two descriptions in order to point out the defects and advantages inherent in a low and high free-board respectively:

Low Free-board.—In rough weather the superstructure might be washed away, the condition of the crew would be a miserable one, every man liable at any moment to be killed or injured, and, if there were passengers on board, they would be made to suffer by a long confinement below deck. The only advantage derived is the diminution of both displacement and target, but, on the other hand, the fighting power is greatly reduced.

High Free-board.—In rough weather the superstructure could receive the spray, the condition of those on board is much better, and the chances of having something washed away are greatly diminished, the crew (and passengers) are in better condition of health. It is true that both target and displacement are increased, but this is largely compensated for by the easier manner in which everything connected with the fighting power of the ship can be handled.

After much unsuccessful research in technical works, for definite conclusions respecting the free-board, I think it should be regulated only by comparison; therefore, I take as a basis the length and height of waves which have been observed by distinguished naval officers. Although these dimensions are not found to be equal, they are nearly proportionate.

In papers written by Admiral Krantz and other observers, a wave 150 meters long may have a height of 12 meters; one of 120 meters long a height of 9·50 meters; and finally, one of 100 meters long a height of 8 meters.

I will use the highest figures for ships which would be fitted for crossing the North Atlantic, high latitudes, or any sea; the mean one for ships crossing the Pacific Ocean; and the lowest for ships crossing between tropics, the Channel, the Mediterranean* and all similar seas.

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*The "mistral," on the coasts of Provence, and the westerly gales in the Channel, must be very nearly equal in their power, and it is believed that it would be difficult to establish a difference in favor of either of these seas.

We start with the following assumptions: In every undulation the adopted ratio ($\frac{1}{12\cdot5}$) between its height and its length will be used, and as it is obvious that a ship in every position at sea has always the same displacement, the drawing and computations by this process are both very simple and rapid.

The length of a ship when increasing can be considered as a chord of a greater arc, and in order to illustrate this fact, I will employ for the free-board the same sketches* I have already used for the increases, but as to the curves I purpose making a further explanation.

The full curved line indicates the location of the types on the crest of a wave, and the dotted line the location of these types when located between two crests; now, if I draw the curve envelope, *i. e.*, a curve tangent to the first two, this new line indicates the surplus or the deficiency of free-board. It will subsequently be demonstrated in what manner these curves will be drawn on plans of form.

I have read in one of Buchanan's papers that his own observations only give for the height of waves about two-thirds the height stated above. I have worked with these figures and found that each tested type would be a good sea-going ship, and according to the observations taken from each type, it was not so. I was not surprised at this result, knowing as I did the disasters which have happened to some liners and other large ships which possessed very much more free-board than was required in using the Buchanan figures.

Elsewhere I have read that waves having from 120 and up to 150 meters of length have been observed, and were respectively 10 and 12·5 meters high; while "Scoresby's" wave of the Atlantic Ocean was 183 meters long and 12·2 meters high. In the latter case the proportion of wave length to height was 15 to 1.

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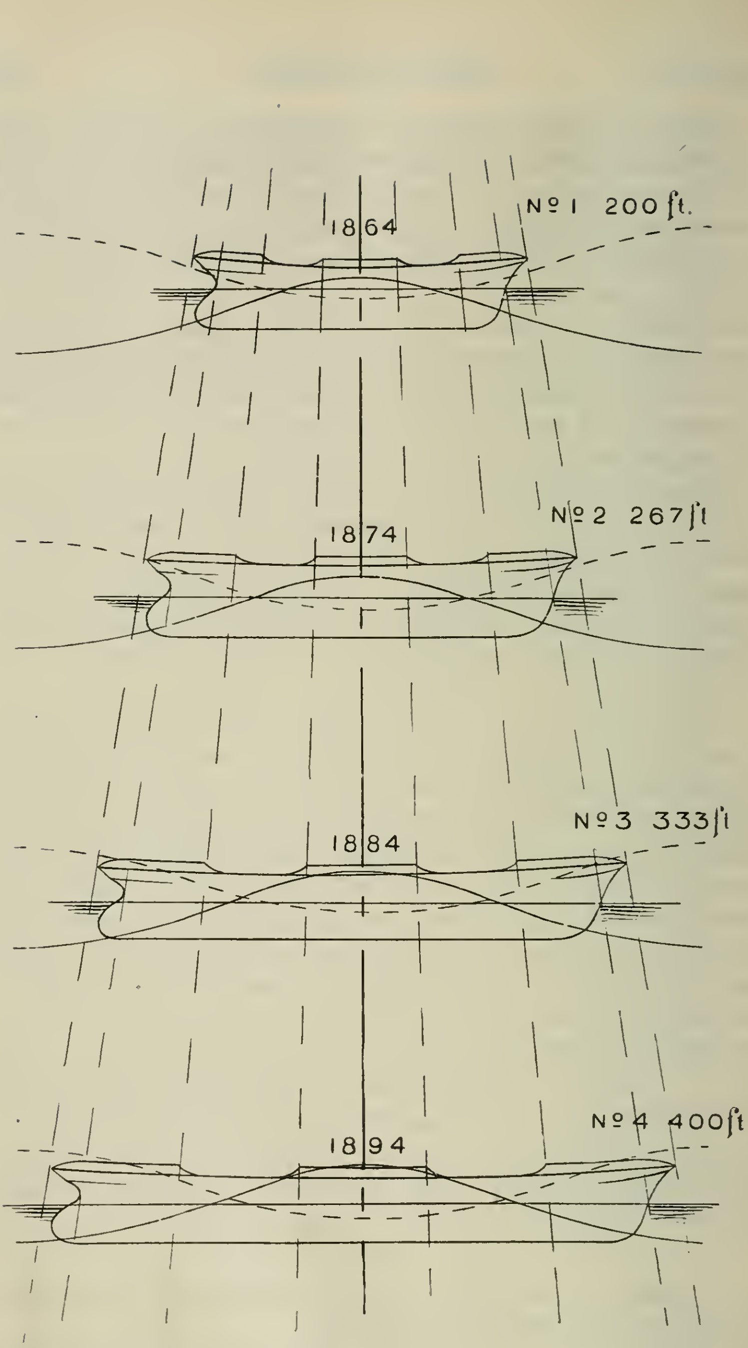
* The dates and dimensions for the following sketches are given only for comparison. (Read English Rules on p. 379.)


Nº 1 200 ft.
1864
Nº 2 267 ft
1874
Nº 3 333 ft
1884
Nº 4 400 ft
1894

I believe that all the above data are nearly correct, and that the difference between their length, height and ratios is attributable to differences in latitude, or seasons, or at least in the intensity of the gale encountered when observations were made.

I do not think it is exact to take a trochoid as a base, because the trochoid is the shape of a wave before a gale is blowing; but when the elements are in fury, a wave consists of three parts: the first, as a base, is nearly of a trochoidal shape; the second is made from a crest, which then is deflected by the wind and breaks on the hollow at the lee-side, taking a cycloidal form, and terminates its run by a more or less wide mass of foam, according to the intensity of the gale encountered; while the third, not of much importance, is only a spray which may be disconsidered.

From the "Proceedings of the International Engineering Congress," "Rankine's Manuals of Applied Mechanics and Civil Engineering," we are informed that "if the periodic motion of the wave particles is in correspondence with the speed of the wave itself, the form of the undulation will be more or less trochoidal, and no breaking or crest-forming action will intervene."

To show the importance of this subject, I will relate the following history of "A Giant Wave:"

The Allan Line steamer *Pomeranian*, from Glasgow, via Moville, for New York, has returned to Greenock, after losing a number of her crew and passengers in a heavy storm.

The *Pomeranian* was about 1,150 miles westward from Glasgow, when she encountered weather of unusual severity. The gales had increased with great suddenness until a heavy sea unexpectedly swept over the deck, carrying everything before it.

The deck saloon, the chart-house, the bridge and the boats were smashed and swept away by the tremendous force of the waves, and, when the sea had passed over, the decks were a scene of ruin, and shrieks of perishing sailors and passengers could be heard in the waves that surged about the dismantled steamer. Captain Dalziel was on the bridge when the wave struck the vessel. He was swept from his post and dashed against the bulwarks, where he lay stunned and helpless. Four passengers, being in the deck saloon at the time of the disaster, were hurled overboard with the ruins of the saloon. They were never seen again, but survivors say a despairing cry pierced the air even amid the thunderous roar of the water.

For a moment after the catastrophe the survivors were too stunned to act. With the captain disabled and the first and second officers drowned, there was no one for the moment to give orders from whom orders were expected. Everyone looked about to see who was in command. Then the third officer quickly brought the crew to their senses and took prompt action to save the steamer and its human freight from further calamity.

All the instruments for navigation had been swept away except the after-compass, by which the steamer had to be navigated. Captain Dalziel was borne below. His injuries were fatal, and he died on the following morning. The crew cleared away the wreckage, and the vessel started on the return voyage, making her way back slowly and carefully to Greenock. The survivors of the passengers and crew are in a very exhausted condition after their terrible experience. Eleven people drowned.

(1) *Height of Free-board from Admiralty Transport Regulations.*—All ships conveying troops are required to have a clear side out of water, when loaded, of three and one-half inches for each foot of registered depth of hold, measured from the upper side of the deck plank next the waterway amidships to the water; or, if a spar-decked ship, of half the above clear side, measured in like manner, but in no case less than four feet six inches. If measured in fresh water one-fourth inch may be abated for each foot of registered depth of hold.	If I applied the rule (1), the free-board for the types Nos. 1, 2, 3 and 4, page 6, would be equal.
(2) *Lloyd's old rule* allows two inches free-board per foot depth of hold, plus one-tenth inch more for every extra foot depth above eight feet.	do. (2) do.
(3) *Mr. Barnaby's rule* allows one-eighth the beam, with the addition of one-thirty-second part of the beam for every beam in the length of the ship above five beams.	In the types Nos. 1, 2, 3 and 4, assuming that the draught is constant, rule (3) will give more rational results than the other two.

According to the first two rules above-mentioned the free-board is regulated in function of one dimension only (the depth), while in the third one it is regulated in function of two dimensions (the ratio between beam and length of ship).

I think these rules are not correct, because the free-board being a volume which is an integral part of the whole hull cannot be regulated, like all volumes, except in function of three dimensions which should represent the displacement at the loaded water-line.

To illustrate this fact I would be glad to have any one apply the above rules to types Nos. 1, 2, 3 and 4, illustrated on page 6.

Observers have been a long time discussing the length and height of waves, but do not agree on this subject.

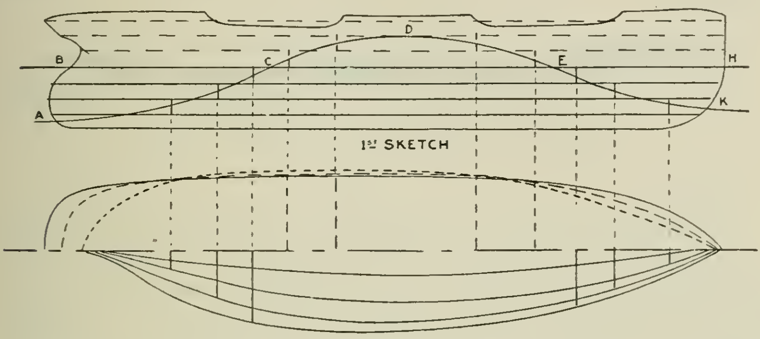
Then the prudence of some persons and the temerity of others, have led us to build ships with more or less freeboard, but generally less, as the latter class largely predominates. In order that no one may be mistaken about the process, I say it is not accurate, but it is close enough, because it has been tried on different kinds of ships which were designed by different naval architects of whom their countries are proud.

By this simple and easy method I have compared seventeen ships. Subsequently, I will give the names of some of these vessels.

Although only approximate, this method is based upon the true principle that each curve is located in function of the displacement. The curve to be adopted may be a trochoid or a wave-line. The following sketches show the manner of obtaining the curve adopted after having determined the length and height of the wave on which the ship is to be navigated.

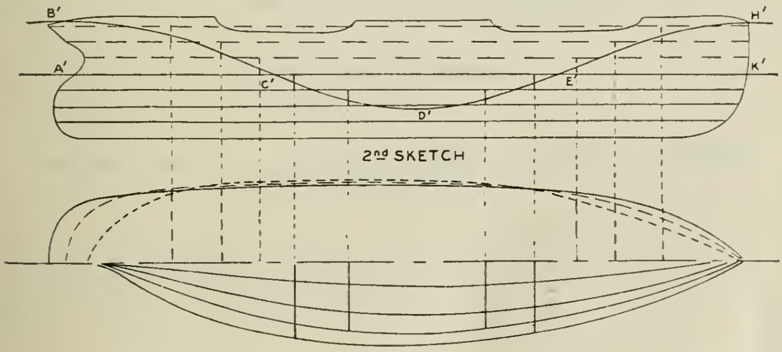
NEW PROCESS FOR FREE-BOARD.

The process consists in tracing the water-lines in two series, having a common axis, the lower series from keel to flotation, when the ship is loaded, and the other from this flotation to the upper part of the hull, poop, bridge and forecastle included.



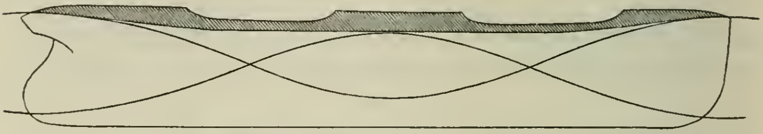
If, after having computed the displacement in still water, I trace a wave line, this curve is intended to limit a volume below equal to the displacement, because whatsoever the position of a ship at sea, and whatever the form of the wave, it is obvious that the displacement is constant. If instead of having her middle part on a crest, the ship is located between two crests, the curve then is as shown below.

In the first sketch, the volume *A B C* plus the volume *E H K* ought to be equal to the volume *C D E*.



In the second sketch we have volume *A′ B′ C′* plus volume *E′ H′ K′* equal to the volume *C′ D′ E′*.

Now, in order to ascertain the surplus of free-board with the location of the curves, as they are drawn on the above sketches, I will trace the two curves together, and with a batten bent tangent to the three summits of the curves, I obtain the curve envelope which resembles the one shown below. The surplus of free-board is indicated by the hatching.

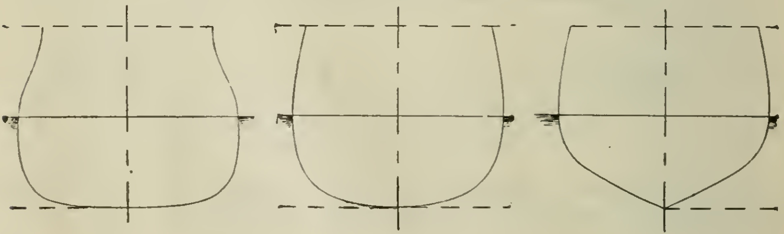


For using this process practically the best way is to draw the curve on a piece of tracing paper, and after having marked the intersections of all water-lines with the curve, the computations of the immersed part should be equal to the emerged one; if not, it would be easy to determine in a sufficiently approximate manner the surface of the flotation corresponding to the curve, and then to add or subtract a part in order to obtain the volumes $ABC + EHK = CDE$.

In the same manner it is easy to obtain $A' B' C' + E' H' K' = C' D' E'$.

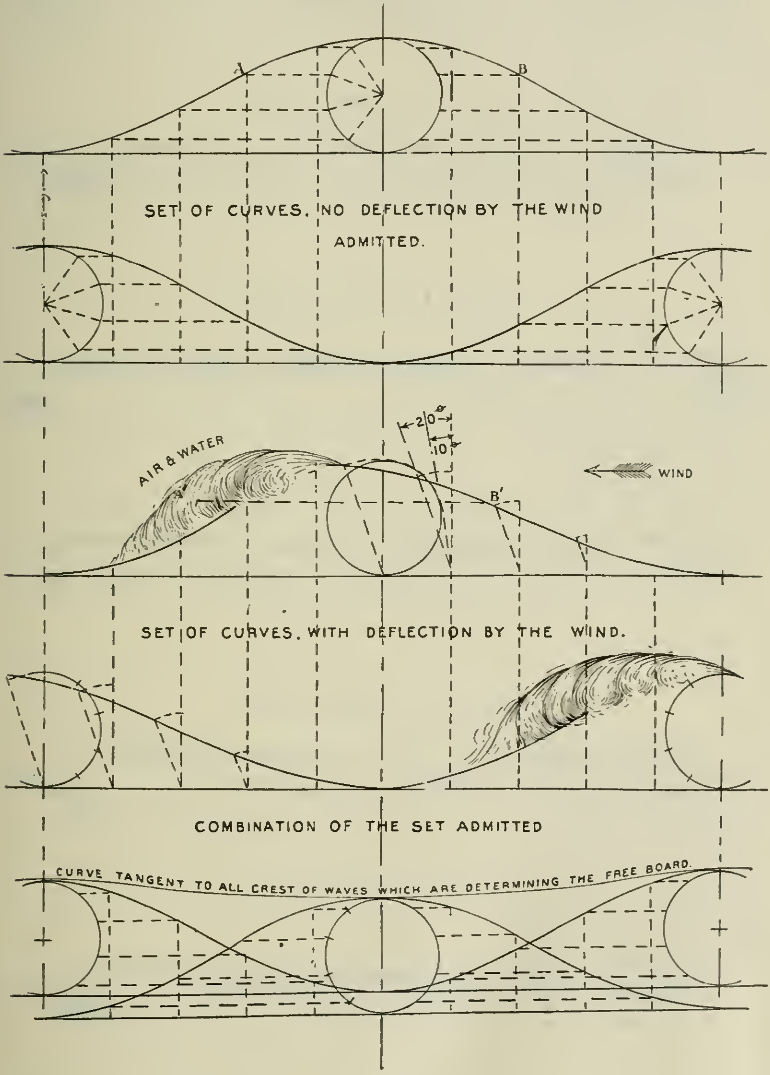
In order to have, at a glance, an idea of the influence of the midship section upon the height of free-board amidships I have made three sketches of midship sections commonly used for ships built for different purposes.

Midship Section for



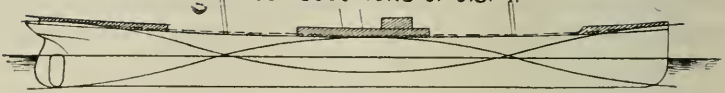
Battleship or Cruiser. Cruiser or Liner. Very Fine Ship.

Comparison and Combination of Sets of Curves.—The distance *A B* can be admitted equal to the mean distance *A′ B′*, and therefore I will use the set of curves not deflected by the wind.

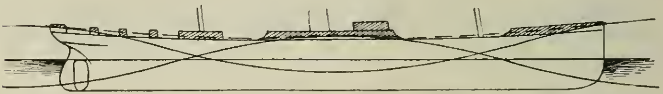

A
B
SET OF CURVES. NO DEFLECTION BY THE WIND ADMITTED.
AIR & WATER
A′
20°
10°
B′
WIND
SET OF CURVES. WITH DEFLECTION BY THE WIND.
COMBINATION OF THE SET ADMITTED
CURVE TANGENT TO ALL CREST OF WAVES WHICH ARE DETERMINING THE FREE BOARD.

It is obvious that the curve tangent cannot be drawn before the places of the first two are determined.

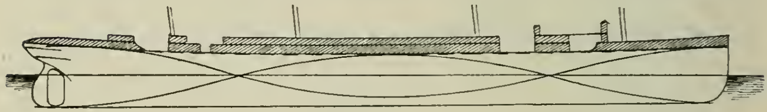
ABOUT 5000 TONS OF DISP'T.



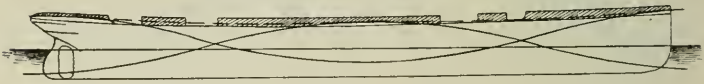
ABOUT 4000 TONS OF DISP'T.



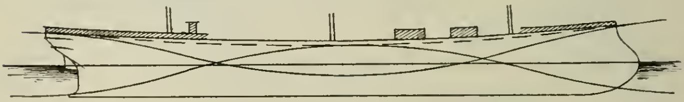
ABOUT 9000 TONS OF DISP'T.



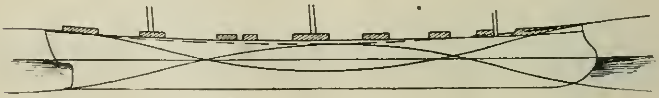
ABOUT 9000 TONS OF DISP'T



ABOUT 7000 TONS OF DISP'T.

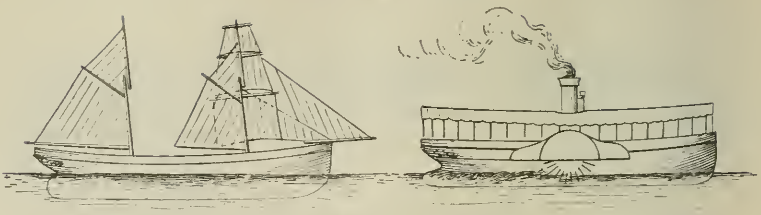


ABOUT 5000 TONS OF DISP'T.



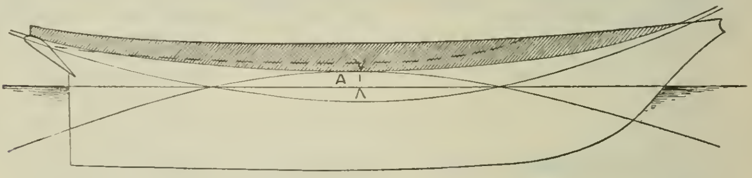
Name.	*Nationality.*	*Kind of Ship.*	*Service.*	*Remarks.*
Uruguay. *Rio Negro.*	French.	Steamers.	From Le Hâvre to La Plata.	In making a comparison between these two types of ships it is easy to see at a glance how much deeper the smaller type could be made in order to be navigated in as good condition as the larger one. I think it is not necessary to say more about these.
Ville de Maranhao. *Ville de Maceio.* *Ville de Victoria.*	French.	Steamers.	From Le Hâvre to La Plata.	
X (design).	French.	Liner.	From Le Hâvre to New York.	The **X** (design) was made several years after the *Normandie*, and was intended to be the first of a type of new liners. The **X** (design) is very good, while the *Normandie* is a little too much immersed, or the free-board not high enough.
Normandie.	French.	Liner.	From Le Hâvre to New York.	
Y (design).		Cruiser.	All seas.	These two types were designed to be built in steel; the first one was not sheathed, but the other one received two thicknesses of teak over her steel shell. The **Y** (design) is nearly in the same condition as the **Z** (design). I should say that both are a little too much immersed.
Z (design).		Cruiser.	All seas.	

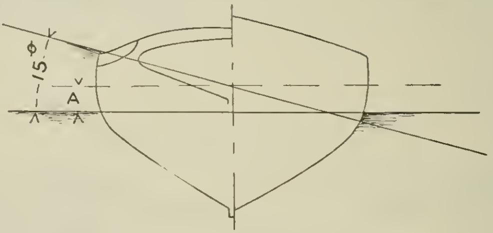
Castor and Pollux.

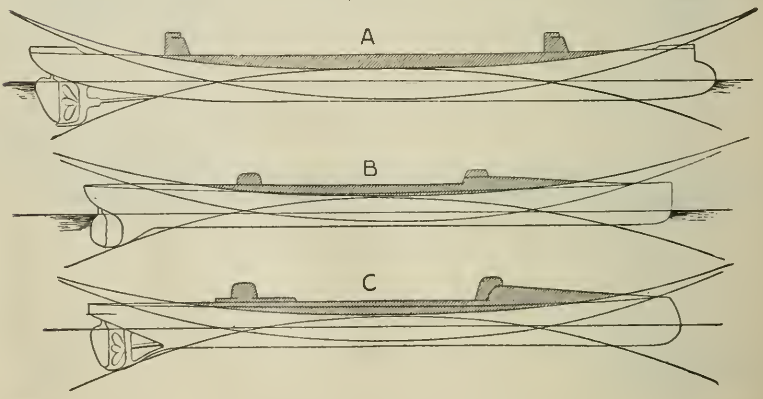


At sea, bound for La Plata River. In service on La Plata River.

The design and building of this ship were very interesting, because her voyage from St. Nazaire to La Plata was made as a sailing ship, the draught not being great enough to permit her to cross the Atlantic Ocean under steam. But, as a sailing ship, by nearly doubling her draught by adding about 100 tons of goods, and in caulking all ports, etc., this very light craft made the voyage in sixty-six days.







Name.	*Nationality.*	*Kind of Ship.*	*Service.*	*Remarks.*	
Milan.	French.	Despatch Vessel	All seas.	Very good.	
Iris.	English.	Despatch Vessel.	All seas.	Bad.	These opinions are perfectly in accordance with the discussion in Parliament on this subject; and in Lord Brassey's *Naval Annual*, they are also the defects noted.
Scout.	English.	Torpedo Cruiser.	All seas.	Bad.	
Mosca.	French.	Tug (twin screw).	La Plata.	Good.	She has been rigged only for sailing from France to Buenos Ayres.
Castor and Pollux.	French.	Light Steamboat	La Plata.	The graphical process was used in order to determine if the increased draught for running in the Atlantic put the ship in good condition as to the free-board. The result was "very good."	
America.	American.	Sailing Yacht.	Pleasure Boat on High sea.	This masterpiece of George Steers, which sailed across the Atlantic in order to race for a cup, which she won, is also very remarkable in having a very good free-board, although very much immersed in proportion to her depth; at the midship section, the proportion of the immersed height to the depth is about two to three. When on the crest of a wave, and inclined at 15°, the gunwale is awash at the middle part only; this fact proves once more that the free-board can be established in a rational manner in accordance with the volume (displacement) and not alone by height. This ship is certainly the best I have studied.	
A		Sea-going Torpedo boat.	High sea.	The types A and C are better than the type B, but none of them can be really considered as a sea-going ship They can go in high seas but not far from the coast, in order that when the captain sees a great change both in barometer and thermometer, he may reach a harbor as soon as possible.	
B		Sea-going Torpedo boat.	High sea.		
C		Sea-going Torpedo boat.	High sea.		

(*a*) For the kind of ship shown herewith (torpedo boats) the curves indicate that the ratios between the principal dimensions have reached a limit which cannot be exceeded.

On the other hand these small crafts have been found very deficient in longitudinal strength. On several occasions, when steaming against a head sea, some plates of the shell were injured.

All these torpedo boats have, or were designed to have, a type of locomotive boiler. I know that several successful experiments have been made with water-tube boilers, which are lighter, although having a higher stamp. By the use of two water-tube boilers, which permits having a free space at the centre line of the ship, it will be easy to make an arrangement to increase the stability of a long, narrow boat.

(*b*) *Remarks on Stability.*—(1) When a ship is located between two crests of waves, *her stability is maintained*, because the displacement being constant, the ordinates of the line of flotation, although diminishing at the middle part, increase very much at each end.

(2) When the ship is located on a crest of wave, *her stability decreases to some extent*, because the displacement being constant, the ordinates, if not giving a great change at the middle part, diminish very much at each end.

It must not be forgotten that in each of the above cases, *a craft is navigated only in disturbed water*, and that principally for this reason, the lack of stability, in the second case, gives a chance of being capsized by the motion of a wave combined with that of the wind.

(*c*) *Conclusion.*—This method has been applied to seventeen ships, in every case giving a result in accordance with the criticism* expressed. Some types of vessels were found very bad and are not represented here, in order to prove that the aim is not to exhibit something odd, and also not to lose time which can be more usefully employed.

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* I was not aware of all the criticisms made with reference to these ships, until after I had proved them by the foregoing method, although I was conversant with some of them previous to that time.

When I design a ship, I can determine in a short time where the surplus or the deficiency of free-board is located; and if I am limited as to the depth, what, as to the upper part, it is necessary to do.

In the case of ships built for rivers, lakes or coasting service, I am obliged to change the draught in order to make them temporarily fitted to run in high seas on the home voyage, or in order to reach the harbor nearest to where they will be used.

From the point of view of naval tactics, in comparing similar types of cruisers or battle-ships, I may say that the ship having some deficiency in her free-board should begin an engagement during fair weather to maintain her advantage, while her enemy, being in a better condition, can fight at any time, and knowing the defect of her adversary, will look for rougher weather, which gives her more chance of winning the day.

APPENDIX.

With reference to torpedo boats, I think that any one may easily be convinced of my ability to maintain the opinions which I have advanced, if he will take the trouble to read the account in the *Illustrirte Zeitung*, on the newest Schichau torpedo boats, built for the Brazilian Government, and which was published in the *Scientific American Supplement* of May 19, 1894, after I had prepared my pamphlet on this subject. These new ships are of a greater size than those which I described, and represent a new method of construction. They may be described briefly as follows:

"One hundred and fifty-two feet six inches long between perpendiculars; new method of construction; double screw, driven by two three-cylinder engines; 2,200 horse-power; the steam generated by two locomotive boilers. When fully equipped, they developed a speed of twenty-eight knots an hour on the trial trip.

"The confidence in them was great, and enough men were found to bravely undertake the hazardous task of carrying it out successfully."

The result of the trial is given below:

Each of the five boats was provided with an experienced captain, a pilot and fifteen men.*

They passed through the Eider Canal to the North Sea. Both there and in the Channel they experienced very stormy weather, and were detained at Dartmouth two weeks by a hurricane. Boats one, two and three, when in the Bay of Biscay, had to pass through a severe test, for a westerly storm drove the *waves as high as a house;* boiling foam and crushing breakers dashed over them, but *they proved to be entirely seaworthy*, passing through the flood as smoothly as an eel, and *plunging with a* GRACEFUL MOTION *from the crest to the trough of a wave. There was no warm food for the crew while the storm lasted; cooking could not be thought of when there was such* TERRIBLE MOTION, *and for days a piece of bread*

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* About two-thirds of the personnel usually carried by this kind of boat. This must be taken into account in considering the volume of air and the room for each person on board when battened down.

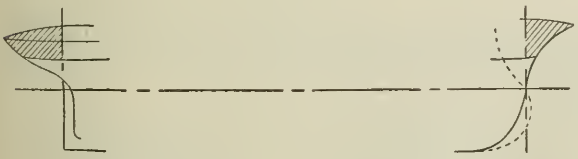
and a swallow of brandy was the only nourishment taken. During the entire voyage only one boiler was used at a time, the boats making a speed of sixteen knots.

Extract from Regulations made by the Board of Trade under "The Merchant Shipping Act, 1890," to come into effect on and after December 1, 1892:

"It will be observed by the tables that they refer exclusively to cargo-carrying vessels. We have not considered it necessary to carry our investigations into the differences which may be made in the loading of passenger vessels.

"In this approximate method, the form of the ship is taken into account by means of proportionate quantities, which are termed coëfficients of fineness, instead of by the exact volume that a displacement scale would give. It is found that the whole internal volume of a ship, as measured for registered tonnage, divided by the product of the length, breadth and depth, measured as described, gives a fractional quantity or coëfficient, which bears a nearly constant relation to the quantity that would be obtained by dividing the whole external volume below the upper surface of the deck by the product of the length, breadth and depth. This fractional quantity is called the '*coëfficient of fineness*' *for free-board purposes.* [On examining these rules I was struck by some facts which I will point out hereafter.]

"Any portion of the erections forward of the fore side of the stern on the load-line, or abaft the after side of the after part on the load-line, is not to be measured for deductions."



Why are the volumes indicated by hatching not taken into account?

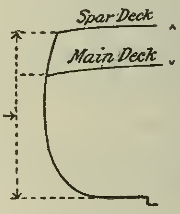
"No alteration is to be made in the free-board in consequence of the coëfficient of fineness being either smaller or greater than those given on the page of the tables from which the ship's free-board is taken."

It seems to me that if you expressed the free-board in function of the fineness, there would not be any exception; but if there be any reasons to justify this exception, which I do not at present see, I would be glad to be informed of them.

In comparing the following tables, I do not see why the Tables A, C and D are established in functions of the volume treated of, while in the Table B the percentage entitled "Reserve Buoyancy" is given in function of the moulded depth.

A summary of these tables will be better than any other explanation that I could give.

		Reserve Buoyancy (*in salt water*). (*Winter.*)
Table A	Cargo-carrying steam vessels not having spar or awning-decks (sea-going iron and steel steam vessels).	From 20·4 to 35·0 per cent.
Table B	Cargo-carrying spar-deck vessels (sea-going steam vessels).	(*Inextricable case*), From ·375 to ·423 of the moulded depth. (Longitudinal strength to be considered.)
Table C	Cargo-carrying awning-deck vessels (sea-going steam vessels).	From 15·0 to 28·0 per cent.
Table D	First-class iron, steel, composite and wood sailing vessels.	From 21·7 to 33·0 per cent.



The free-board will be increased if the 'tween-deck height is more, and decreased if it is less, than 7 feet.

I think that the variation in percentage will be understood from the following summary giving some data relative to the above tables:

	Length of Ship.	*Moulded Depth.*
Table A, ...	From 72 feet to 408 feet.	From 6′—0″ to 34′—0″
Table B, ...	From 240 feet to 444 feet.	From 13′—0″ to 30′—0″
Table C, ...	From 168 feet to 408 feet.	From 14′—0″ to 34′—0″
Table D, ...	From 55 feet to 310 feet.	From 5′—6″ to 31′—0″

"In these tables the word free-board denotes the height of the side of a ship above the water-line at the middle of her length, measured from the top of the deck at the side, or, in cases where a water-way is fitted, from the curved line of the top of the deck continued through to the side. The free-boards and the corresponding percentages of reserve buoyancy necessary for flush-deck steamers not having spar or awning-decks, for awning-deck steamers, and for flush-deck sailing vessels, are given in Tables A, C and D, for vessels of these classes, and of various dimensions and proportions. The free-boards necessary for spar-deck steamers are given in Table B. The latter are determined by considerations of structural strength, and they denote the limitations to depth of loading which are thereby imposed upon first-class vessels of this type. The free-boards and percentages of reserve buoyancy then obtained being in excess of what would otherwise be required, the amounts of such percentages are not given in Table B.

"The exact free-board required for a given ship belonging to any of the classes comprised in Tables A, C and D, may be calculated by constructing a displacement scale to the height of the deck to which the free-board is measured, so as to give the whole external volume up to the upper surface of that deck. The percentage of the total volume which is given in the tables as the reserve buoyancy for a vessel of given type and dimensions, will be the amount of volume that must be left out of the water.

"No reduction of free-board should be allowed on account of deck-erections in spar-deck and awning-deck steamers."

A great many objections could be made to the deck-erections, but in the present discussion they are of too little importance to be spoken of.

The authors of the *Board of Trade Regulations*, some of which are summarized herein, travelled for a while in every country, to consult the ship-builders, ship-owners, and as many persons as possible having more or less direct interest in this important question, in order to be able to formulate for the present time rules which, when admitted as regulations, should not give too much trouble in the use of types of ships which were more or less suitable as regards the amount of security for crew and cargo.

If it is wise to limit the free-board according to the seasons, seas to be navigated, kind or class of ships, in an inverse ratio to the quality of their construction and material, it leads one to suppose that many of these ships should be altered or reinforced to become economic according to their size, while many others will become obsolete by the appearance of a more powerful and suitable class. This is so, because the law of economy in exploitation is favorable to the increase of dimensions which, for a while, was checked by the fact of not having harbors deep enough, or a personnel sufficiently well trained or numerous enough to make such start in the ship-building of the country where such a want was expected.

Accordingly, I am of the opinion that the above method is only a transitory one, that should be considered only as provisional, and ought to be successively modified. It then would become more and more rational. These regulations are also objectionable because the base taken from the internal volume to regulate the outside part varies according to the kind of ship; but if the base were taken from the outside (displacement), I think this method would be much improved.

I will conclude with the following remarks:

If a number of pounds per square inch could be fixed as a minimum of resistance corresponding to the material used; if all kinds of construction (transverse and longitudinal) with any material could be admitted; and if we would avoid, as I have already stated, (1) the trouble of having two coëfficients of fineness, one for running at the required speed, the other to determine the free-board; and (2) the trouble of constructing two scales, one for the displacement, the other for determining the reserve buoyancy; then, under these circumstances, I think that ships, merchant-men and men-of-war, now so far different from their old types, and for which the data are generally given in order to solve the corresponding displacement from which the free-board would immediately be deduced, would be designed on a more rational, simple and uniform method.

SUMMARY OF DATA AND QUANTITIES TO BE KNOWN FOR A GIVEN PROGRAMME FOR A NEW TYPE OF SHIP.

Merchantman.		Man-of-war.	
Data.	*To Solve.*	*Data.*	*To Solve.*
Service.	Weight of hull (ready for sailing)	Service and Class.	Weight of hull (ready for sailing).
Speed.	Weight of engines (working).	Speeds.	Weight of engines (working).
Cargo.	Weight of coal.	Coal endurance.	Weight of coal.
Passengers (if any)	Weight of goods (stowed).	Armor.	Weight of armor.
	Weight of quarters (complete).	Ordnance.	Weight of ordnance (with magazines).
	Weight of personnel (with bags or trunks).		Weight of quarters (complete).
	Weight of passengers (with trunks).		Weight of personnel (with bags or trunks).
	Weight of provisions (stowed).		Weight of provisions (stowed).
	Weight of ballast.		Weight of ballast.
	Weight of sundries.		Weight of sundries.
	Total = displacement.		Total = displacement.

Now, how much free-board is required in order to obtain a good habitability, and not a ship which must be battened down as soon as the sea becomes rough?

BOOK NOTICES.

The Mechanics of Hoisting Machinery, including Accumulators, Excavators and Pile Drivers.—A text-book for technical schools and a guide for practical engineers. By Dr. Julius Weisbach and Prof. Gustav Herrmann. Authorized translation from the second German edition, by Karl P. Dahlstrom, M E., late instructor of mechanical engineering at the Lehigh University. With 177 illustrations. New York: Macmillan & Co. 1893. Price, $3.75.

This excellent translation will be welcomed by English-speaking students and engineers, as adding another volume to their working library on engineering mechanics on the high authority of Dr. Weisbach. The previously-translated volumes covering theoretical mechanics, steam engines and hydraulics, and the machinery of transmission, are recognized as standard works in their several departments. The present volume on the mechanics of hoisting machinery is in nowise inferior in abundance of illustration and thoroughness of treatment.

The subject-matter covers levers and jacks, tackle and differential blocks, windlasses, winches and lifts, hydraulic hoists, accumulators and pneumatic hoists, hoisting machinery for mines, cranes and sheers, excavators and dredges, and pile drivers: eight chapters in all, covering 332 octavo pages, including 177 well-executed engravings, and index.

The style is lucid, the text entirely free from all extraneous matter, and the abundance as well as excellence of the engravings render mere descriptive matter almost unnecessary. The treatment, as is the case with all of Dr. Weisbach's works, is largely mathematical, and, as this volume is intended primarily as a text-book for technical schools, no other method would so well serve the purpose.

It is a matter of regret that the translator did not add an appendix to the present work for the benefit of American students, including examples of the more recent developments in hoisting machinery; for example, the mechanism of hydraulic high-speed passenger elevators by Otis, Crane, Graves, and others. In travelling cranes especially, the mere matter of illustration and description of the later examples by the Morgan Engineering Company, William Sellers & Co., and the Yale & Towne Manufacturing Company, would have added value and completeness to what is in all other respects a good book. W. M. B.

Mechanical Drawing: Progressive Exercises and Practical Hints. By Charles William MacCord, A.M., Sc.D. 4to. New York: John Wiley & Sons. 1893. Price, $4.

The author has brought together in this volume selections from his previous writings on the subject, and has arranged them in a logical sequence, one subject leading up to another with increasing difficulty, the elegance and clearance of the text rendering his meaning easily understood in all cases. Chapters I and II of the first part—progressive exercises—are particularly happy, and, although containing many suggestions and directions which a capable and skilled draughtsman would take exception to, have a good tendency, forming a training for students which is superior to that usually furnished them by technical colleges, which are apt to be deficient in this branch, due to the fact that the instructors are generally selected from graduates without experience in actual work, who have never had the advantage of the competition and atmosphere of the draughting room and the criticisms of the shops, and consequently hand down and perpetuate the absurdities of the usual college course.

The author is to be congratulated on having finally adopted, in Chapter III, the third angle of projection, in which the imaginary planes are transparent, and thus adding the weight of his authority in the direction of making theoretical teaching conform to what long shop experience has proven to be the most clear, sensible and reliable arrangement of the different views in a drawing. He sadly dilutes the good effect of the reform, however, by advocating special exceptions, and by showing illustrations which grossly violate it. His positive stand against bottom-views, in which he says: "Under no circumstances should a projection be made which involves the idea of the eye being placed beneath the object and looking upward," is absurd, and innumerable cases are constantly occurring in which this arrangement is not only allowable, but also is the only proper one. His—"consequently, a top-view may be placed either above or below the elevation"—is a natural sequence of false premises, and constitutes the fundamental error of the customary teaching, to which is traceable more shop mistakes than from any other cause, excepting incorrect dimensions.

Chapter IV, on objects in "Inclined Positions," is the gem of the book, and constitutes one of the finest things ever published on the subject of drawing, and in a very useful direction, which is rarely followed in teaching. Chapter V, on the helix, is excellent. Chapter VI, on intersections and developments, is all that could be desired as to excellently selected examples, methods of working them out and clearness of explanation, and is only marred by the want of uniformity in the location of the top-views, which, although not misleading in this case, yet compels useless thought, and tends to form careless habits in this regard which will eventually get the student into trouble.

Chapter VII, on isometrical drawing, introduces and explains the subject in the clearest manner possible. It is valuable for reference in the rare cases where it would be of any utility. Chapter VIII gives excellent and useful instruction as to the drawing of a propeller wheel.

The second part of the book, Practical Hints to Draughtsmen, would be harmless if read only by draughtsmen, but unfortunately it will be studied and considered as authoritative by numerous students of engineering, who, when getting at actual work, will use the peculiar and local conventionalities described, to the great annoyance and delay of everyone who handles their drawings. The only way to attempt a convincing criticism of it would be to re-draw the great majority of the illustrations in a proper manner, such as any competent and experienced draughtsman would use, and then point out the differences and explain the reasons for them, which is, of course, impracticable.

T. S.

*Preliminary Reports upon a New Declinometer for Orientation, and a New Variometer.** By Adolph Fennel. With one lithographic plate. Reprint from Mittheilungen aus der Markscheidekunst, published by the Society of Mine Surveyors of Rhenish Westphalia. Freiberg in Sachsen. Craz & Gerlach (Joh. Stettner). 1894. Pamphlet, 12 pages.

This pamphlet, issued by Otto Fennel, manufacturer of geodetic instruments at Cassel, describes two instruments designed for meridian observations in mines: the declinometer, for ascertaining the position of this meridian, and the variometer for determining variations in the position of that meridian.

In both instruments a long thread made from melted quartz crystal is suspended in a vertical tube, and at the lower end of this is hung a horizontal magnet, consisting of a light steel tube, which acts as the compass needle, and in which is placed transversely a small mirror. When in use, the instrument is attached to the theodolite or transit in such a way as to stand directly before the object end of the telescope of the latter. To this telescope is attached a short tube containing a half-lens, an inclined mirror and a glass scale. Through an opening in the upper part of this tube a ray of light falls upon the mirror and is reflected forward through a scale into the body of the declinometer, where it is reflected by the mirror in the magnet and passes back through the half-lens and through the object-glass of the telescope on the transit.

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* Vorläufige Mittheilungen über ein neues Declinatorium für Orientirungsmessungen und über ein neues Variometer.

The variometer is similar in form to the declinometer, but, instead of being attached to the transit, it is provided with a small telescope for observing the motions of the swinging magnet, and the latter contains, instead of the mirror used in the declinometer, a prism. T.

A Text-book on Roads and Pavements. By Fred. P. Spalding, Assistant Professor of Civil Engineering in Cornell University. 213 pages. 12mo. Cloth. $2.00. New York: John Wiley & Sons. 1894.

This little volume, indicating as it does the general awakening of public interest in the matter of the improvement of highways, aims to set forth in convenient shape, and within small compass, the broad principles underlying the practice of road construction, and no effort is made to present in detail the methods usually employed, or the results obtained.

After discussing the principles of road location, and those governing the selection of the cross-section, the author proceeds to the discussion of the improvement of country roads, and then devotes a chapter to their construction. The remainder of the work is devoted chiefly to the subject of city streets, under which head, brick, asphalt, wood and stone-block pavements are treated. T.

A Treatise on Hydrostatics. By Alfred George Greenhill, Professor of Mathematics in the Artillery College, Woolwich. London: Macmillan & Co. (New York, 66 Fifth Avenue.) 1894. 536 pages, including index.

This is a convenient treatise, although rather highly mathematical for the average reader. Besides the subject of hydrostatics proper, those of earth-pressure, of pneumatics (including aëronautics), hydraulics and the mechanical theory of heat, are briefly handled. The numerous illustrations have been carefully prepared and executed expressly for this work.

The author's use of English leaves something to be desired, as may be seen from the following paragraph: "As these instruments are usually small, the inch and ounce are used as British units of length and weight; but, better still, the centimetre and gramme in questions relating to their use; and then densities will be given in oz./in.^{3}, or with the metric units the densities and specific gravities will be the same, a great numerical simplification."

Little as we know respecting the Keeley motor, most Philadelphians who have heard something of its peculiarities will be surprised by the statement on p. 21, that it "is a paradoxical instrument, devised with the intention of utilizing the hydrostatic energy of pressure."

The work derives much of its value from the fact that it is in great par made up of discussion of existing problems, for which the author has had free recourse to the periodical and other technical literature of the present day. It is plentifully furnished with examples for practice. T.

Brick for Street Pavements. An account of tests made of bricks and paving-blocks, with a brief discussion of street pavements and the method of constructing them. New edition, with a paper on "Country Roads." Prepared for the Engineers' Club of Cincinnati, April, 1894. By M. D. Burke, C.E. Cincinnati: Robert Clarke & Co., 61–65 West Fourth Street. Fifty cents.

The author here presents us with a valuable little treatise upon paving-brick, based upon tests made of that and other materials for the village of Avondale, a suburb of Cincinnati. The tests were made upon sixteen samples forwarded by manufacturers and dealers in response to invitations. The object of the author was to determine the crushing and transverse strengths of the materials submitted, their resistance to abrasion and to impact, their rate of absorption and their chemical composition. Two-inch cubes were cut from the interior of the bricks submitted, and were tested in a Riehlé machine, after being carefully dressed. To determine the resistance of the specimens to abrasion and to impact, they were placed in a revolving cylinder with loose pieces of iron.

The subject-matter of the pamphlet is not confined to the behavior of the individual bricks under test, but is extended to the matter of brick street-paving in general. The author submits a form of specification which he believes to be free from many of the faults usually abounding in such documents. While the material of the bricks is in so far vitrified that the alkalies and alkaline earths are made to form vitreous compounds with the iron and the silica, the author considers the application of the term "vitrified" to the brick itself as a misnomer.

The author claims that under moderate traffic the cost of maintenance of properly laid brick pavements will be less than that of any other form except granite blocks.

Under the head of "Country Roads," the author briefly outlines the controlling principles which should be borne in mind by those who are placed in charge of road improvement. T.

A Text-book on Roofs and Bridges. Part III; Bridge Design. By Mansfield Merriman, Professor of Civil Engineering in Lehigh University, and Henry S. Jacoby, Associate Professor of Civil Engineering in Cornell University. 425 pages. New York: John Wiley & Sons. 1894. $5.00.

Students of engineering, and that branch of the profession which concerns itself with bridge and roof design, will cordially welcome this third part of the excellent series which Professors Merriman and Jacoby are placing before them, and which contains nearly twice as much matter as the first two volumes of the series combined.

It has been well said of the present work that it demonstrates that book-construction is scarcely less an art than bridge construction.

In the present volume the authors have called to their aid a considerable number of experts in various branches of the art of roof and bridge construction. Thus, Mr. Geo. H. Thomson describes a ballast-floor plate-girder bridge, of his design; Mr. C. C. Schneider, two bridges built by the Pencoyd

Company; and Mr. John Sterling Deans, one by the Phœnix Bridge Company; while elevated railroad structures are discussed in the chapter contributed by Mr. O. J. Marstrand, formerly assistant engineer of the Brooklyn elevated railroad.

After reviewing briefly the history of the science, and presenting a list of works upon the subject, the authors discuss, in Chapters II and III, respectively, the general principles of design and some of the principal details of trusses.

Then follow analyses of four different trusses, namely, a triangular roof truss with wooden compression members, a plate-girder bridge, a pin-connected truss, and a riveted triangular truss for a highway bridge. In the discussion of the pin-connected truss, the authors quote the specifications published by Mr. F. H. Lewis, of this city, in the Proceedings of the Engineers' Club of Philadelphia, Vol. IX, January, 1892. T.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 17, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Oct. 17, 1894.

JOSEPH M. WILSON, President, in the chair.

Present, forty-six members and eight visitors.

Additions to membership since last report, eight.

Prof. Wm. H. Bristol, of Hoboken, N. J., presented a description of his recently devised registering thermometer, designed to record continuously, and at any required place about a works, the temperature of heating chambers, ovens, and the like. The speaker exhibited and showed the operation of one of the instruments.

Mr. W. F. Z. Desant, of New York, exhibited and described the construction and operation of an artificial respirator of his invention, intended to serve as part of the equipment of hospitals, life-saving stations, and elsewhere, to aid in the resuscitation of the apparently drowned, or of those suffering from asphyxiation from the inhalation of poisonous gases, etc.

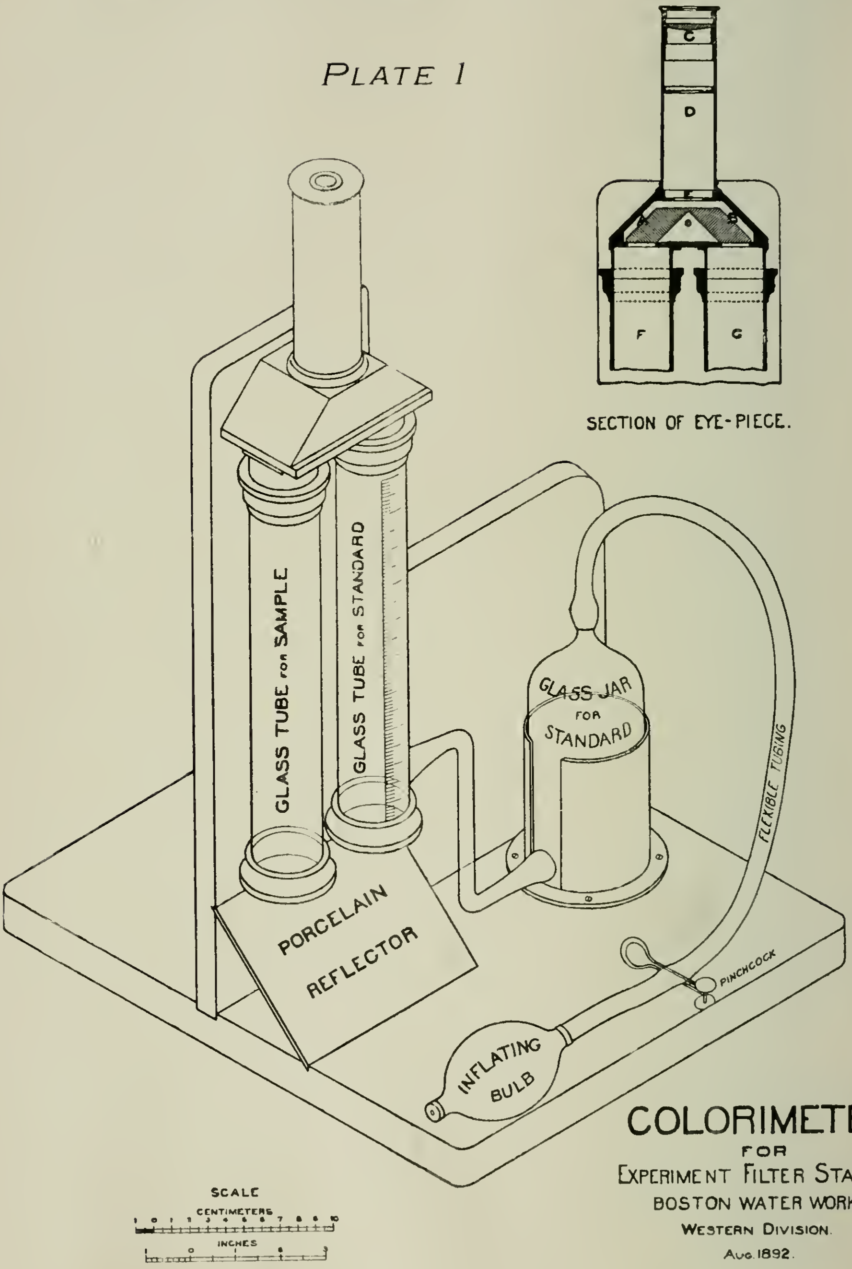
Mr. W. S. Cooper exhibited a remarkably fine specimen of cast aluminum in the form of a large bath-tub cast from that metal. He made, in connection therewith, some interesting remarks concerning the adaptability of aluminum for this and other household articles and utensils.

Mr. W. N. Jennings showed a series of lantern views of characteristic London street scenes, taken by himself last summer, which were well received.

The Secretary presented his monthly report.

Adjourned. WM. H. WAHL, *Secretary.*

PLATE 1



COLORIMETER
FOR
EXPERIMENT FILTER STATION
BOSTON WATER WORKS
WESTERN DIVISION.
AUG. 1892.

JOURNAL

OF THE

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXVIII. DECEMBER, 1894. NO. 6

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE COLOR OF WATER.

BY DESMOND FITZGERALD AND WILLIAM E. FOSS.

As many cities and towns are obliged to depend upon surface waters for their supplies, and as surface waters are liable to be discolored by the vegetable matter with which they come in contact, making them objectionable in appearance, it is important to have an accurate scale with which to measure the amount of the discoloration.

For several years past, this matter has received much attention upon the Boston Water Works. One of the principal sources supplying the city of Boston is that of the Sudbury River. The area of the water-shed above the point of taking, is about seventy-four square miles. On this area several large storage reservoirs have been built for the purpose of equalizing the yield of the streams. As the sites of the reservoirs have been mostly stripped of all organic matter, the effect of storage is to reduce the color of the water delivered by the feeders, but as it is impracticable to keep the water in store long enough to decolorize it completely, much study has been given to the source and amount of the color delivered by the streams supplying the reservoirs. It has been found, as was expected, that the swamps and meadows were the principal sources of color.

In July, the color of the water coming from the swamps is a rich reddish-brown, and in the autumn, after the leaves have fallen, the color has more of a greenish cast.

The color of the brooks varies constantly during the year, depending largely upon conditions which cannot be now discussed. In winter the color is naturally low. In the spring the color is high, reaching its maximum in June, and a second maximum occurs in December.

In making plans for the improvement and drainage of the swamps it became important to be sure of the measurement of the colors, and as the color of the Boston water is almost an exact gauge of the organic matter which it contains, it also became important that the color of the water delivered to the consumers should be readily and accurately measured on some correct scale. It is the purpose of the writers of this article to consider here the matter of scale and methods of comparison.

When solar light is transmitted through a water containing foreign matter, some of its components are wholly or partially absorbed and the transmitted light is more or less colored in consequence. The color depends on the nature of the missing rays, or is the resultant of the rays which have been transmitted. The greater the depth of the water through which the light is transmitted, the greater will be the effect on the component and the more marked the color. Light which has traversed a depth of two meters of distilled water has only a very slight blue color, hence it can be said that in pure water all of the component colors are transmitted with almost equal facility.

The color standards at first used on the Boston Water Works were prepared by diluting portions of a highly colored water with distilled water until the colors matched those produced by nesslerizing varying amounts of an ammonia solution (0·01 Mg NH_3 per cc.) in fifty cubic centimeters of distilled water; the color being recorded as the number of cubic centimeters of the ammonia solution used.

These water standards are, therefore, as near as possible duplicates of the nesslerized ammonia standards employed for reading the color of water. They are much more convenient to use, because their color does not change as rapidly as that of the nesslerized ammonia solutions, which have to be mixed fresh at every observation. A set of standards having been prepared in the above manner, the color of a water is determined by comparison in Nessler tubes, which are of glass, about 15 to 20 millimeters in diameter and 300 millimeters in length and closed at one end. The tubes are filled with the different standards to a depth of 200 millimeters. A similar tube filled to the same depth with the water to be examined is moved along the scale until a point is reached where its color matches one of the standards. All of the tubes are viewed against a white background. When the color of the water falls between two consecutive standards, the color is estimated by the observer.

These natural water standards, although an improvement over the nesslerized ammonia standards, were found to be very unsatisfactory, for the following reasons:

They did not remain constant in color, but were found to change even when kept in the dark.

Standardizing a set against the nesslerized ammonia was very difficult, because the conditions when preparing a set of nesslerized ammonia solutions had to be always exactly similar in order to obtain uniform results.

It was also found that owing to irregularities in the scale the color of a water when diluted with distilled water would not vary with the dilution.

It was found that the platinum standard recently suggested by Dr. Allen Hazen* was not open to these objections, and was a much better standard to use.

"On the platinum standard the color of a water is the amount of platinum, in parts per ten thousand, which in acid solution, with so much cobalt as will match the hue, produces an equal color in distilled water."

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* *Amer. Chem. Journal*, Vol. XIV, No. 4.

In preparing a set of standards, a standard solution having a color of 5·00 is usually prepared, and from this the lower standards are prepared by dilution with distilled water.

On this standard then, from the method of its preparation, the color of a water when diluted with distilled water will vary directly with the dilution.

The platinum standard which has been found to match the Boston water best, contains twenty-five parts of cobalt to fifty parts of platinum. It has been found to keep for months without change if protected from dust.

The method of comparing colors in Nessler tubes was not considered satisfactory. The color of a water falling between two consecutive standards depended largely upon the judgment of the observer. It was believed that a more convenient method could be obtained, and the colorimeter, shown on *Plate 1*, was designed to overcome these objections. *Plate 1* shows an isometric projection of the complete instrument and a section of the eye-piece. The latter consists of two totally reflecting prisms *A* and *B*, and a magnifying lens *C*. The lens is free to slide in the brass tube *D*, so that it can be focussed on the upper face of the prisms. The field of view is cut down to a circle by a diaphragm *E*, at the lower end of the tube *D*.

Rays of solar light from some uniform source, after passing through the water placed in tube *F*, which has a plate-glass end, enter the prism *A*, and emerging, illuminate one-half of the circular field of view.

Rays of light from the same source after passing through the standard solution in tube *G*, enter prism *B*, and are totally reflected at its surface, and emerging illuminate the other half of the field of view. The colors produced by the absorption of the two liquids can then be readily compared and brought to the same value, as follows:

The standard solution is held in a glass jar, and is connected by means of a glass tube with the standard tube.

The top of the jar is furnished with a piece of flexible rubber tubing, terminating in an inflating bulb. By means of the latter the observer increases the depth of the standard solution in the standard tube, until the color produced on the field of view matches that of the water in the other tube; he then closes the pinch-cock on the tubing and reads the color of the water from the scale on the standard tube.

The color of a water determined by comparison in the colorimeter, should differ slightly from the color obtained by comparison in Nessler tubes and using the platinum standard, due to the fact previously mentioned that distilled water has a slight blue color. In the colorimeter the portion of the tube above the standard is not filled with distilled water, while in the Nessler tubes it is filled.

The following readings of a set of platinum standards in the colorimeter having some 1·00 platinum standard in the jar, are the average of two sets of readings by independent observers. They show that the maximum error does not exceed 0·02.

In cases where greater accuracy is required for water having a low color, a 0·50 standard should be substituted for the 1·00 in the jar.

Platinum Standard.	*Colorimeter Reading.*
0·10	0·115
0 20	0·22
0·30	0.32
0·40	0·40
0·50	0·50
0·60	0·595
0·70	0·70
0·80	0·80
0·90	0·895
1·00	1·00

The rapidity with which comparisons could be made by means of the colorimeter led to quite extended observation to determine the irregularities of the nesslerized ammonia and natural water scale already mentioned. On the lower portion of *Plate 2* these irregularities are illustrated graphically. The upper scale represents a uniform gradation, and the middle one the gradation corresponding to the nesslerized ammonia and natural water scales, and represents the scale as determined by the average of observations made by two independent observers upon a set of natural water standards which had just been standardized against the Nessler solutions. The determinations were made with the colorimeter having some 1·00 natural water standard in the jar.

The lower scale shows the irregularities of the natural water and nesslerized ammonia scales as determined from the average of observations on fifteen sets of natural water standards made by three independent observers.

The differences between the two scales are probably due to the difficulty previously mentioned in preparing the nesslerized ammonia solutions and also to changes having taken place in the natural water standards after being standardized.

That the irregularities in the nesslerized ammonia and natural water scales are due to the method of preparation and not to any error introduced by the colorimeter, was shown by preparing a set of colors by diluting a 1·00 natural water standard with distilled water, and then reading these colors on the colorimeter, having some of the original 1·00 natural water standard in the jar. The following are the results:

Dilutions of 1·00 Standard.	*Reading on Colorimeter.*
·10	·095
·20	·21
·30	·295
·40	·405
·50	·52
·60	·60
·80	·80
1·00	1·00

From these investigations it was learned that the nesslerized ammonia and natural water standards were of very little value for accurate color readings.

To illustrate the misleading results obtained by using these standards, the following example may be taken:

Water having a color of 0·40 on the Nessler scale before filtration was found to have a color of 0·10 after filtration, showing a reduction of seventy-five per cent. by the process of filtration. By the uniform scale, however, shown on *Plate 2*, this reduction is really only about fifty per cent.

Before the present form of the colorimeter was finally adopted, two methods were suggested by which the colors produced by the absorption of light by the standard solution and those produced by the water alone could be made to match.

The first was to vary the depth of the water under examination, while the depth of the standard remained constant. The second was to vary the depth of the standard, while the depth of the water remained constant.

A study of the first method showed that the depth of water could be varied between certain limits, only and that it was better, for accurate results, to keep the water under examination of a fixed depth. As the bottom of the tube is approached, the change in color, corresponding to any given decrease in depth of water, increases rapidly. It was decided that 200 millimeters would be the most convenient length for the tube, and that the scale divisions should not be less than two millimeters to be read accurately: also that a difference in reading of one scale division should not make an error in the resulting color of more than four per cent. It was also assumed for purposes of calculation that the color of the water and standard varied directly with the depth; that is, if the color of a water in a depth of 100 millimeters equals that of the standard in depth of 200 millimeters, then the color of the water would be twice that of the standard. If the color of the water in depth of twenty millimeters equals that of the standard in depth of 200 millimeters, then the color of the water would be ten times that of the standard.

The following table shows the increase of color corresponding to equal variation in depth of the water when a standard of 0·50 is used. It can be seen from the last column of this table how rapidly the differences of color, due to a decrease in depth of ten scale divisions, increases in the lower portion of the tube. It is thus evident that the readings of color in the upper portion of the tube will be of much greater accuracy than those in the lower portion:

Standard.	Depth of Standard. M. M.	Depth of Water. M. M.	Calculated Color of Water.	Difference of Color for 10 Scale Divisions.
0·50	200	200	0·50	—
"	"	180	0·55	·05
"	"	160	0·62	·07
"	"	140	0·71	·09
"	"	120	0·83	·12
"	"	100	1·00	·17
"	"	80	1·25	·25
"	"	60	1·67	·42
"	"	40	2·50	·83
"	"	20	5·00	2·50

In the upper diagram, Plate 2, the colors obtained by calculation have been plotted for several different standards; the abscissas represent the depth of water in the tube and the ordinates the calculated color when using the standard marked on each curve.

The cross on each of the curves shows the point at which the error in a color reading, resulting from an error of one scale division in reading, would equal 4 per cent, For all waters having colors darker than this, a new standard must be employed.

In this way it was found that where waters having colors ranging from 0· to 1·00 are common, at least three standards are necessary. For quick, practical work this method would be very inconvenient.

The second method, however, was found to have none of these objections; it gave readings of equal value in all parts of the tube, and readings from 0· to 1·00 could be obtained with a single standard, as shown by following table:

Standard.	Depth of Water. M. M.	Depth of Standard. M. M.	Calculated Color of Water.	Difference of Color for 10 Scale Divisions.
1·00	200	200	1·00	·10
"	"	180	·90	·10
"	"	160	·80	·10
"	"	140	·70	·10
"	"	120	·60	·10
"	"	100	·50	·10
"	"	80	·40	·10
"	"	60	·30	·10
"	"	40	·20	·10
"	"	20	·10	·10
—	—	0	0	—

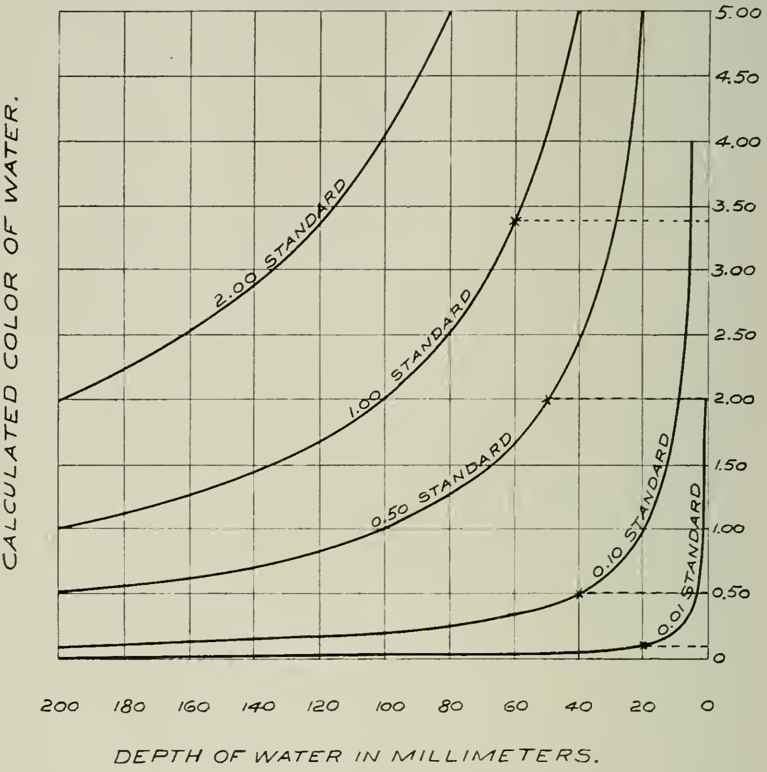
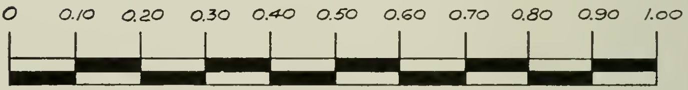
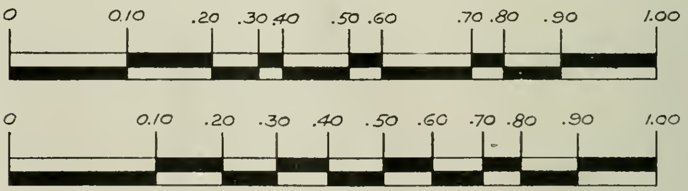


PLATE 2.

UNIFORM SCALE.



NATURAL WATER OR NESSLERIZED-AMMONIA SCALES.



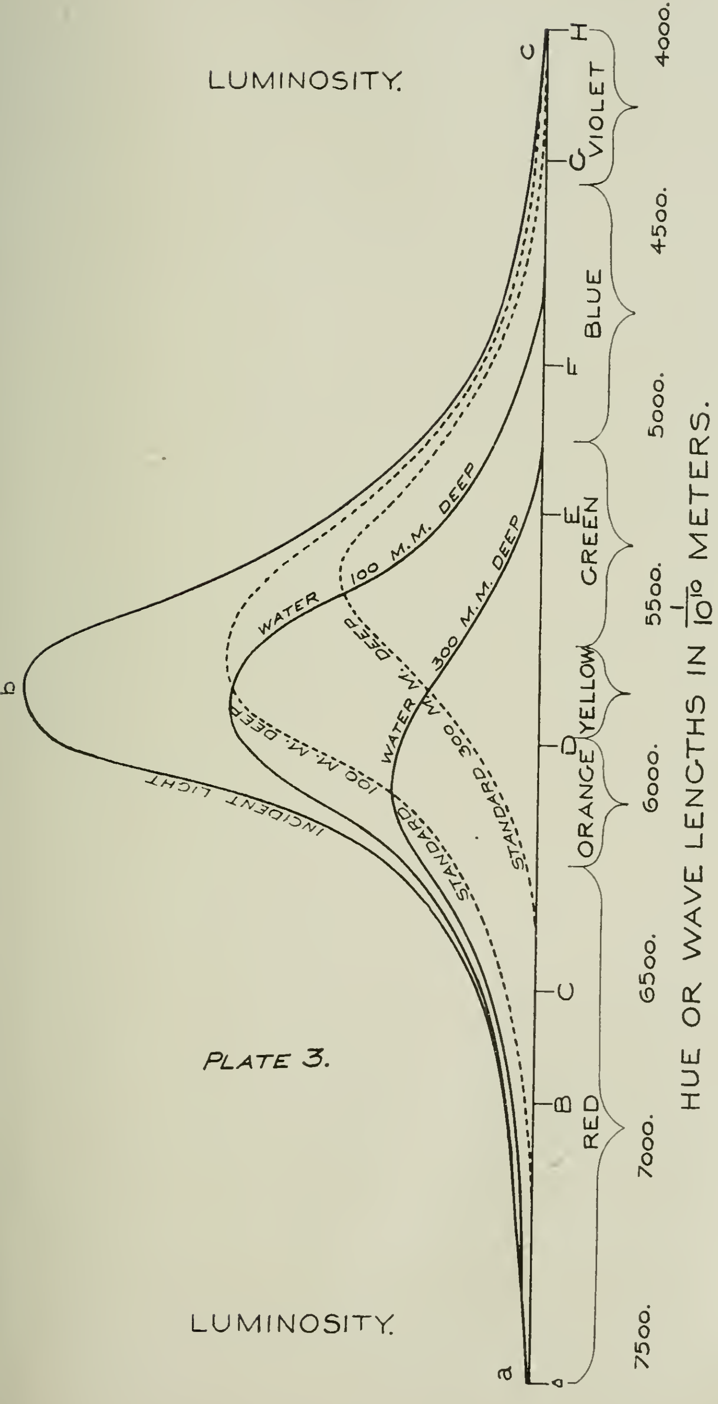

LUMINOSITY.
LUMINOSITY.
a
b
c
INCIDENT LIGHT
WATER 100 M.M. DEEP
100 M.M. DEEP STANDARD
WATER 300 M.M. DEEP
300 M.M. DEEP STANDARD
STANDARD
H
G
F
E
D
C
B
VIOLET
BLUE
GREEN
YELLOW
ORANGE
RED
4000.
4500.
5000.
5500.
6000.
6500.
7000.
7500.
HUE OR WAVE LENGTHS IN $\frac{1}{10^{10}}$ METERS.

PLATE 3.

The platinum standard has been adopted for use on the Boston Water Works.

For converting any former readings on the Nessler or natural water scale to the platinum, the following table can be used. It was prepared from observations on fifteen sets of natural water standards.

TABLE FOR CONVERTING COLORS ON THE NESSLERIZED AMMONIA AND NATURAL WATER SCALES, TO EQUIVALENT VALUES ON THE PLATINUM SCALE.

Natural Water Scale	·10	·20	·30	·40	·50	·60	·70	·80	·90	·100
Equivalent on Platinum Scale	·18	·26	·33	·39	·46	·52	·58	·63	70	·81

For standards darker than 1·00 no satisfactory comparisons have yet been made. For reading colors darker than 1·00 it has been found best either to read in shorter depths or else dilute with distilled water in order to bring the color within the range of the 1·00 standard. The latter method has been adopted on the Boston Water Works. The reason for this is that it is often difficult to compare the dark waters with the standard owing to a difference of hue. It has been found that the amount of light which passes through a number of equal layers of an absorbing solution, diminishes in geometrical progression as the number of layers increase in arithmetical progression. Thus if I denotes the intensity of the incident light, Ia will be the intensity after transmission through unit thickness, where a is a proper fraction, and depends upon the nature of the substance and the refrangibility of the light employed. For a given wave length, a will be different for different substances; and for a given substance, a will vary with the wave length. The quantity a is termed the coefficient of transmission.*

It is because of the fact that the coefficient of transmission for the different rays varies with different solutions that we sometimes find a water matches the standard very closely in hue in a short depth, but appears of quite a different hue in a greater depth. This can be represented by a diagram as follows. Let the ordinates of the curve $a\ b\ c$

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* Thomas Preston, *The Modern Theory of Light.*

in diagram, *Plate 3* represent the intensities of the incident rays of light from the red to the violet, which fall upon a water, and the standard with which it is compared. Then assuming the following coefficients of transmission for a depth of 100 millimeters.

	Standard.	*Water.*
Red	·1	·9
Orange	·5	·8
Yellow	·6	·6
Green	·9	·5
Blue	·9	·1
Violet	·9	·1

The intensities of the different rays after traversing 100 millimeters would equal their original intensity multiplied by their respective coefficients.

The intensities after traversing a depth of 300 millimeters would equal the original intensity multiplied by the third power of their respective coefficients giving the following:

	Standard.	*Water.*
Red	·001	·729
Orange	·125	·512
Yellow	·216	·216
Green	·729	·125
Blue	·729	·001
Violet	·729	·001

Plotting these values, gives the curves in the diagram. The upper curve shows the intensity of the different colors in the incident light, and the four other curves show the intensities after having passed through 100 and 300 millimeters of the standard and water respectively. Comparing the intensities after passing 100 millimeters of the water with those of the standard for the same depth, it is noticed that they do not differ much in hue or luminosity. Comparing the intensities after passing 300 millimeters of standard and water, it is noticed that the hue of the water has approached the red, while that of the standard has approached the blue.

These hues would therefore be quite different, and could not be accurately compared. The relative luminosity has also changed, the standard having become somewhat brighter than the water.

Color readings made by different observers, have been found to agree to within ·02. Occasionally differences of ·05 or more are found. These differences are usually found in cases where the water from turbidity or other causes differs from the standard in hue. This renders the comparison difficult, and the result depends largely upon the judgment of the observer.

The accuracy at present attained in color readings is probably quite sufficient for practical purposes.

The principal difficulty in the way of greater accuracy in color readings is the difference in hue between the prepared standard and the water. Maxwell, Young and Helmholtz claim that all color perceptions are due to the simultaneous excitation of three sets of nerve ends in the eye, and that all colors can be produced by a combination of three colors, red, green and blue in the proper proportion.

It is possible that a colorimeter might be constructed on this principle by employing standard red, green and blue solutions, so arranged that they could be combined in all proportions. A solution would also probably have to be employed to give the effect of turbidity to the standard.

With a colorimeter of this kind much more time would be required to make the comparison.

Prof. Ogden N. Rood* has employed these three constants to define completely a color.

(1) Purity, or freedom from white light.

(2) Luminosity, or brightness.

(3) Hue, or wave length.

To measure the color produced by the absorption of a water it could be arranged so that the measurement of the first constant would not be necessary. The light after passing through the water, would consist of several components. It would be necessary to separate these by means of a prism or grating, and compare the spectrum thus obtained, with the spectrum of the original light. The measurements of the hues could then be accurately made, and the luminosity would remain as a photometric problem.

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*Text-Book of Color. By Ogden N. Rood. 1892.

It appears, therefore, that in order to obtain much greater accuracy in color readings than is at present possible, more time and expensive apparatus must be employed. It would tend to uniformity of results and facilitate comparisons if all color readings were made on the uniform depth herein described, all water darker than 1·00 being diluted, as set forth on page 409.

One of the purposes of the writers of this article is to urge all chemists, analysts and others interested in matters of water supply to adopt the methods herein described, unless some better method can be found.

THE PHOSPHATES OF THE WORLD.*

By Francis Wyatt, Ph.D.

[*Continued from p. 347.*]

The cost of producing one ton of rock in dry marketable condition, is at the present moment generally allowed by the river companies to be about $2.75 per ton, including fifty cents royalty to the State, and well-managed land companies with no royalty to pay, place their cost of production at from $2.75 to $3 delivered free alongside vessels in Charleston harbor.

Of the total annual output, about two-thirds of nearly all the land-rock, are consumed in the United States, principally in Charleston, Richmond, Baltimore, Philadelphia and New York; the river-rock, which constitutes the remaining third, is exported.

As a raw material of the first-class in the manufacture of soluble and available phosphates, South Carolina rock is everywhere held in the highest esteem. In Europe it is very popular, and, being of unvarying quality, has yielded results that cannot be surpassed by any other phosphate as an all-round staple, uniform and reliable article.

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*A Lecture delivered before the Franklin Institute, January 12, 1894.

No absolute opinion can be expressed as to the probable extent and capacity of the yet untouched or unexploited land deposits and it would be manifestly absurd to attach undue importance to any estimate that might be formed. At the same time, my own investigations prompt me to suggest that it may probably extend over some thirty square miles. If the yield of this area were to approximate the present average of 750 tons to the acre, the conclusion would be that South Carolina may still produce about 14,000,000 tons of land phosphate.

As the time rolls on the manufacturing requirements of the State will increase in large proportions, and I sincerely hope and believe that this source of consumption will eventually absorb all that can be produced, and leave nothing available for foreign markets.

PHOSPHATE ROCK (WASHED PRODUCT) MINED BY THE LAND AND RIVER MINING COMPANIES OF SOUTH CAROLINA, SINCE THE DISCOVERY OF THE DEPOSITS.

	Long Tons.
1867, year ending May 31st	6
1868, " "	12,262
1869, " "	31,958
1870, " "	65,241
1871, " "	74,188
1872, " "	58,760
1873, " "	79,203
1874, " "	109,340
1875, " "	122,790
1876, " "	132,478
1877, " "	163,000
1878, " "	210,322
1879, " "	199,365
1880, " "	190,763
1881, " "	266,734
1882, " "	332,077
1883, " "	378,380
1884, " "	431,779
1885, " "	395,403
1885, (June 1st to December 31st)	277,789
1886, (calendar year)	430,549
1887,	480,553
1888,	448,567
1889,	548,585
1890,	537,149
1891,	400,000
1892,	350,000

Passing now to those deposits so recently developed in Florida, it is only fair to remark that they were really discovered and located in various directions throughout the State many years ago. They, however, were never believed to be of sufficient importance either in quantity or quality to merit serious attention, and like many of our natural resources, remained long dormant and unthought of.

The first serious attempt to develop them in 1888 was marked by the outbreak of a perfect fever of speculation. At that time our total annual output of phosphate was about 500,000 tons, nearly all of which was raised in South Carolina, about 200,000 tons being exported and the balance used at home.

The difficulties between the Coosaw Company and the South Carolina State authorities, brought about by the action of Governor Tillman, had only just arisen, and as the temporary suspension of this company's gigantic operations threatened a considerable decrease in production, buyers became anxious to secure their needed supplies, and sellers advanced their prices.

To the initiated, this was an intelligible and natural situation, on the one hand there was the probable deficiency of 100,000 tons by the Coosaw Company; on the other, there were the customers of this company anxious to supply their needs and ready to abide by a rise in price rather than be left unsatisfied. A fictitious activity was thus imparted to the industry, of which few, if any, of those who rushed into the Florida fields took the trouble to ascertain the true inwardness. To these eager speculators the only prominent phases were the demand for phosphate and the vast quantities ready to be exploited in Florida, at an exceptionally low price, and of exceptionally high quality.

They ignored the all important fact that the present demand for consumption of the entire world for mineral phosphates does not attain more than 2,000,000 tons, including all kinds and qualities, and disregarded the circumstances that three-fourths of this quantity are being raised in other countries, from mines almost as productive as our own, and that South Carolina might eventually be equal to any calls we might make upon her.

Thus company succeeded company; exaggerated values were placed upon Florida lands; the possibilities of consumption and production were ridiculously overestimated; and in lieu of looking to our own agriculture for an outlet, and thus awakening the interest of American farmers, the general attention was turned to Europe as a more proper, because supposed unlimited, consumer.

The result of such a "boom" and of such ignorance has been widespread and deplorable. The foreign buyers who were at first so skeptical of the existence and value of Florida phosphates, became seriously concerned at their abundance, and their anxiety for future supplies changed to apprehension when they saw themselves menaced with a glutted market. They knew and understood the impossibility of finding an outlet in any of the ordinary channels of trade, for such a flood of material as that with which they became threatened, and they took advantage of their knowledge to break down the hitherto firm prices of phosphates. So thoroughly did they master the situation, that the hapless Florida miners are now entirely at their mercy, and are confronted by quotations which have closed most of the world's phosphate mines, and at which even South Carolina, despite her natural advantages, can no longer make both ends meet.

This state of affairs would be sufficiently discouraging, even if the "boom" had resulted in a serious increase in the consumption of American phosphates. We might have found in such an increase some consolation from the fact of displacing foreign products, either at home or abroad, though prices were thereby lowered and mining profits reduced. A careful and impartial study of figures however, shows that this meagre satisfaction is denied us, for no such enormous increase in our total production, consumption or exports, has in reality taken place.

In the year 1890, for example, the total sales of American phosphates from all sources amounted to about 600,000 tons, and our average prices were $7 per ton for that which contained sixy per cent., and $12 per ton for that containing seventy-five to eighty per cent. phosphate of lime, both free on board out-going vessels.

In the year 1892 we increased our sales by eighteen per cent., or in other words, we sold about 700,000 tons. This surplus of only 100,000 tons, had such an extraordinary effect upon the markets of the entire world, that its disposal entailed a fall in price to $4.50 and $6.50 per ton for the respective qualities mentioned.

This remarkable disturbance, caused by this slight excess (a large proportion of which was of exceptionally high grade and good quality) graphically illustrates the present want of flexibility in the fertilizer markets, and, in my opinion, not only argues badly for the immediate future but should be a significant warning to our producers not to further overstep the bounds of prudence.

Whether the disturbed equilibrium can be restored now that we are at war with all other phosphate producers of the world, and how and when phosphate mining can again become one of our really profitable undertakings, are serious problems, but it is certain that, in proportion to the world's demands, there are now too many in the business, and that we must look forward to the collapse of a large majority of the mining companies, before entertaining hope for any sensible relief. The operation of the law of supply and demand is always absolute and inflexible, and it must be appreciated before the future of Florida as a phosphate producer can be established on a commercial basis. Directly its applicability is fully realized, her miners will be satisfied to rank as large contributors to the world's necessities, and will always then command sufficiently remunerative prices to repay them for the expenditure of capital and labor.

The geological formation in which the very remarkable Florida phosphate deposits are found, I may broadly summarize as being divided between the Eocene, Miocene and Pliocene ages. It is chiefly composed of:

(1) Original pockets or cavities in the Vicksburgh limestone filled with hard and soft phosphate and debris.

(2) Mounds or beaches rolled up on elevated points, and chiefly consisting of huge bowlders and large and small fragments of phosphate rock.

(3) Drift or disintegrated rock commonly called "pebbles"

covering immense areas, chiefly in Polk and Hillsboro counties, and underlying portions of Peace River and its tributaries.

The work of exploitation by regular mining and hydraulic methods has been prosecuted on a large scale at various points, which, if taken in their entirety, would probably cover an area of some 275 miles long and nearly seven miles wide on the western side of the Peninsula.

In several of the mines, notably in those of Marion and Citrus counties, the beds of phosphate have extended in many cases uninterruptedly over several acres and have been worked in the form of quarries. These beds have shown themselves to be combinations of the "original pocket" and the "mound formation," and the superincumbent material or over burden is principally sand, of an average depth of eight or ten feet and without any admixture of phosphate. The phosphate rock itself is sometimes in the form of enormous bowlders lying either singly, or cemented together in groups with clay, and sometimes in the form of small fragments imbedded in a white plastic or friable mass resembling kaolin. This white material is, like the fragmentary rock, undoubtedly the result of a natural disintegration, caused by the rolling, attrition, or concussion of the hard bowlders. The thickness of the phosphatic stratum varies within a range of from five to fifty feet, and cannot therefore, be computed with any accuracy into an average; and the limits of the superficial area occupied by the combined "pockety" and "mound" formations are so sharply defined, that the readily exploitable deposits of bowlder rock phosphate frequently terminate very abruptly and give place to an unimportant drift of fragmentary material. This drift generally crops out at the surface through the sand, and may sometimes be followed for such long distances without leading to a pocket of bowlders of exploitable value, that I believe it quite safe to place the actual phosphate producing area at a maximum of no more than 3 per cent. of that commonly attributed to the phosphate belt.

When the exploitable pockets are of any considerable depth, they yield large quantities of merchantable phosphate, but I have found that as a rule they are very superficial, and, in some of them, the underlying limestone is so near to the surface and the phosphate itself so mixed up with other and valueless material, that profitable extraction is impossible.

In the districts where no bowlders or other variety of hard-rock phosphate have been discovered, and where only "pebbles" abound, this capriciousness of the formation is much less marked, and, in fact, an unusual degree of regularity may be said to characterize the occurrence of what is commonly known as the "land pebble" phosphate throughout the extensive area in which it has been found. This area may be roughly said to take its point of departure in Polk County a little south of Bartow, and thence to practically continue with a gradually narrowing tendency to within a very short range of Charlotte harbor. The "pebble" country is flat, swampy, and extremely unhealthy. It is intersected at frequent intervals by the Alafia, Manatee, Peace and other rivers, rivulets and streams, and extensive exploratory work has demonstrated that it is largely underlaid with a nodular phosphate stratum of a thickness varying from a few inches to thirty feet, with an overburden of sand and clay that may be fairly averaged at about eight feet.

The most important working centre for "pebble" phosphate is Peace River, which rises in the high lake lands of Polk County, and flows rapidly southward into the Gulf of Mexico. Its course is extremely irregular, and its bottom is a constant succession of shallows and deep basins. Lakes Tsala, Opopka and Chillicohatchee, and Pains and Whidden Creeks are its chief tributaries, and I have satisfied myself by careful examination that they are the main sources of its phosphate deposits, since the phosphate "pebbles" are without doubt washed out from their banks and borne along their beds into the river by the torrential summer rains.

The phosphate "pebbles" when pumped out of the river and freed from impurities and dried, vary in size from a grain of rice to about one inch in diameter, and they are intimately mixed up with the bones and teeth of numerous extinct species.

The only difference between them and the "land" pebbles, is that the latter are of a lighter color and are imbedded in a matrix of sand and clay, to which they frequently bear the proportion of about twenty per cent. by weight.

Although the origin of these Florida deposits has naturally been very much discussed, and a great number of more or less plausible theories has been advanced, I doubt whether any particular one has yet been sufficiently supported by evidence to warrant its general acceptance. I have personally devoted to it a great deal of observation and thought, and so far as I have gone I believe the most satisfactory explanation is that which ascribes them to a deposition resulting from previous solution. Apart from the probable existence of bird guano deposits in large quantities on their exposed surfaces, the Vicksburgh limestones all contain in themselves notable proportions of phosphate of lime, and the seas of that age were certainly charged with sufficient carbon dioxide to dissolve both carbonate and phosphate of lime in large quantities. Having entered into solution the phosphate, at a subsequent period, was re-deposited under conditions favorable to its separation. What these conditions most probably were I need not pause to discuss at any length, but I think it will be obvious that they might have been either a simple interchange of bases between the dissolved phosphate and the limestone bed, or a mere lowering of the solvent powers of the water by evaporation and loss of carbonic acid gas. In either case the final result would be the formation, principally in the neighborhood of the rock cavities produced by the leaching process, of large and small estuaries, and those estuaries being certainly replete up to a certain point, with life and vegetable matter, the continuous concentration of the waters ultimately induced complete precipitation and a multitude of readily conceivable subsequent processes of decomposition and metamorphism.

It may be very rationally surmised, for example, that among the chief of these processes and decompositions, when the "drying-up" was nearly complete, would be the combination of the liberated phosphoric acid, and the ammonia, resulting from the breaking up of the albuminoids of the organic matter. The diammonium phosphate thus formed would be dissolved by subsequent waters, and, percolating through the overlying mass of the deposit, would saturate the calcareous marls as well as the soft and porous limestone underneath. A double decomposition would thus be induced, with formation of hydrogen calcium phosphate and ammonium carbonate: $2\,(NH_4)_2\,H(PO_4) + 2\,CaCO_3 = Ca_2\,H_2\,P_2O_8 + 2\,(NH_4)_2\,CO_3$.

In whatever manner it was originally formed, whether as a residium from leaching, a deposition from solution, or a product of decomposition and metamorphism, the phosphatized stratum was eventually cracked and broken up and was then hurled into yawning gaps and from one fissure to another. At the end of the tertiary period came the succeeding seas with their deposits of drifts and shells, sands, marls, clays and other transported material, and it is easy to assume that those portions of the phosphate crust which were not embedded in permanent limestone fissures or caverns during the Miocene age, subsequently became very thoroughly disseminated and disintegrated. The masses were rolled about and intermixed with sand, clay, and marls, and were banked up with them in various mounds or buried in depressions in conformity with the violence of the waters, or with the uneven structure of the surface to which they were transported.

Occasionally this drifting mass found its way into very deep hollows, in regions where considerable depressions were brought about by the sinking and settling of the substratum. At other times it was rolled to and deposited on slightly higher points. In the first of these cases we find a vast and complete agglomeration, comparable to an immense pocket, of broken-up phosphate rock, finely divided phosphate *débris*, sands, clays and marls, all heterogenously mixed in together. In the second case we find the phosphate in large bowlders, sometimes weighing several tons and intermixed with relatively, but, small proportions of any foreign substance.

THE CHEMICAL COMPOSITION OF FLORIDA PHOSPHATE is as variable as its physical aspects, and I present the following averages of my own analyses for the purpose of general illustration:

	Bowlders washed, crushed, dried.	*Land Pebble.*	*River Pebble.*	*Soft White.*
Moisture	0·32	0·84	0·76	1·13
Organic and volatile	0·97	5·25	7·03	3·06
Phosphate of lime	82·80	70·50	60·84	72·23
Carbonate of lime	4·57	5·01	9·85	10·03
Carbonate of magnesia . . .	0·46	0·32	0·87	0·74
Fluoride of lime	4·34	5·27	4·99	3·86
Oxides of iron and alumina,	2·20	2·96	3·57	4·01
Insoluble siliceous matter .	4·20	9·00	12·03	4·54
Loss in analysis and undetermined	0·14	0·85	0·86	0·40
	100·00	100·00	100·00	100·00

It will be seen from these figures that, quite apart from its abundance, we are dealing with a product of the very first rank for the purposes of the fertilizer manufacturer. The unfortunate fact remains, however, that owing to certain established trade customs arising out of the long-continued use of South Carolina phosphate, there is no remunerative market in our own country at the present time for high-grade material, and this, consequently, has to be exported. Similarly established trade customs. arising out of similar causes, prohibit foreign .buyers from accepting any phosphates containing a higher maximum than three per cent. of oxides of iron and alumina, and this compels our miners to guarantee an absolute limit to these impurities in all their shipments.

The now generally adopted plan for working the bowlder deposits in such a way as to free them as far as possible from the undesirable iron and alumina, chiefly present as adhering particles of clay, was, I believe, first suggested by myself in 1890. It consists in crushing all the big boulder rock to a sufficiently small size, and passing it, together with all the *débris* that comes from the mine, through washers of the type known as the Tennessee log-washer. After being thus entirely freed from sand and clay, and passed through screens of various sizes, it is finally dried in open kilns, built up on logs of pine. The cost of production in this method of mining when economically carried out, as it is, for instance, in the washing-plants built by McLanahan & Stone, averages about $3.50 per ton and there is no waste of phosphate.

The land pebble phosphates have not yet been extensively worked, and as they are even more intimately mixed up with clays than the hard rock phosphate, there is still some doubt as to the most economical way of winning them. Some of the large concerns in Polk County employ a floating dipper-dredge set in a deep trench, which is deepened and extended as the deposit is removed. The entire mass of phosphate and matrix is brought up to the surface by the dredge, and, as in the case of the bowlder rock mines, is first dropped into a species of disintegrator or crusher. Thence it passes on into a revolving-washer mounted on the same structure. From the washer, the matrix and water return to the trench, while the clean nodules are carried by a spiral conveyor to a steam-heated dryer on a barge alongside. From the dryer they fall into a revolving-screen, which removes any remaining particles of adhering sand, and the now marketable phosphate is caught up by elevators and delivered on board railway-cars standing on a track parallel with the trench.

The exploitation of the "river pebble" is performed by means of a ten-inch centrifugal steam suction-pump placed upon a barge. The pipe of the pump having been adjusted by ropes and pulleys, is plunged ahead from the deck of the dredge into the water. The mixture of sand and phosphate sucked up by it is brought into revolving-screens of various degrees of fineness, whence the sand is washed back into the river. The cleaned pebbles can be discharged from the screen into scows at the rate of about twelve tons per hour, and the product is floated down to the drying-house, where it is taken up by an elevator and dried by hot air.

The total cost of raising, washing, drying, screening and loading "pebble" phosphates on cars, is stated to be $2 per ton. As in the case of South Carolina, I have compiled the following table, showing the quantity of

PHOSPHATE (ROCK AND PEBBLE) OF ALL GRADES MINED BY THE LAND AND RIVER COMPANIES OF FLORIDA SINCE THE DISCOVERY OF THE DEPOSITS :

	Long Tons.
1888, year ending December 31st,	3,000
1889, " "	4,100
1890, " "	46,501
1891, " "	112,482
1892, " "	300,000

I have now finished what is, at the best, only a very brief and rough description of our phosphate beds, and I should probably best recognize your endurance by at once releasing you. While I freely recognize, however, that I shall be imposing on your good nature if I crave your indulgence for a few moments longer, I venture to do so because I much wish to touch upon two very important points bearing on my subject. The first of these relates to the practical use of phosphate of lime by the agriculturist, and the second to the desirability of universally adopting some correct and definite method for its analysis.

The phosphate miner, as we have seen, does not sell his product to the farmer, but to the manufacturers of fertilizers, who first grind it to an extreme fineness, and then mix the powder with about its own weight of weak sulphuric acid. Two out of the three molecules of lime originally combined with the phosphoric acid, being thus transformed into gypsum, a more or less soluble article is obtained which is the basis of all artificial fertilizers, and which is popularly known as superphosphate. The reason why this acidulated compound is preferred to the raw material is to be found in the generally admitted fact that tricalcium phosphate is very sparingly and very slowly soluble in the water of the soil, and that no element can penetrate into the interior of a plant unless it be in solution.

A great many attempts to use it as a direct fertilizer have demonstrated that the availability of raw mineral phosphate entirely depends upon the fineness of the powder to which it may be reduced, and the nature and composition of the soil in which it is to be employed, and it is a matter of the greatest difficulty to attain the requisite degree of disintegration by any sufficiently cheap mechanical means. In this respect we are, in fact, not very much further forward now than we were in 1857, when Liebig recognized the difficulty and proposed to solve it, by adopting a chemical method of decomposition which enabled the farmer to obtain practical results from the use of mineral phosphates within one year, instead of waiting three or four. That the chemical treatment does not in reality do anything more than break up the primary molecular formation of the tricalcic phosphate, is proved by the fact that superphosphate of lime is only soluble in water so long as the mono-calcic form retains its ascendency. . Directly it reaches the soil, especially where carbonates are in abundance, the unsatisfied phosphoric acid unites with various earthly bases and becomes insoluble. To put it plainly therefore, the issue so far as the farmer is concerned, revolves upon a matter of time and of money. He might buy a ton of raw phosphates, ground as finely as possible, and containing, let us say, fifty-five per cent. of tricalcic phosphate for $10. If his land were tolerably acid, and this, of course, is seldom the case, he would get a rapid return, but if it were not, his raw phosphate would only decompose very slowly and he would have to wait three or four years before obtaining any appreciable results from his outlay. On the other hand, if he buys a ton of superphosphate for $20 containing only thirty per cent. of calcic phosphate made soluble, and applies it to a phosphate-barren soil, he produces the desired effects on his crop the same year. This is no hypothetical statement; I have seen the thing done over and over again in my own experience, and have satisfied myself that the true explanation of the different results is the one I have already given. The mere decomposition of the tricalcic phosphate into the acid salt ensures an absolute state of division which is maintained despite the subsequent reversion, and an intimate and immediate contact with the acid sap of a greater number of root hairs being thus facilitated, the ready ab sorption of the dissolved phosphate by the plant, is naturally assured.

These views will be endorsed by all the officials of our agricultural experiment stations who have made the comparative use of the finely ground raw mineral phosphates and of superphosphate, and I believe that their results with the former have always varied in accordance with the nature of the soil in which the experiments were made; and have fully confirmed the conclusions formulated in 1857 by De Molon, who after very extensive trials of ground raw coprolite in many different departments of France, said that:

(1) Raw phosphate might be used with advantage in clayey, schistous, granitic and sandy soils rich in organic matter.

(2) If these soils were deficient in organic matter or had long been under cultivation, it might still be used on them in combination with animal manure.

(3) It may not be used with advantage in chalky or limestone soils.

I, therefore, take it that the term soluble, as applied to phosphate must be accepted in a relative sense, and I consider and have always urged that the use of both raw and manufactured articles is a matter which calls for intelligent discrimination on the part of the farmer. He might find that in one portion of his lands raw phosphates mixed with his compost heaps would soon dissolve and yield very profitable and rapid returns, while in another portion, owing to a different constitution of the soil, they would remain inert for an indefinite period.

In England and in Germany, a great deal of stress is laid by chemists upon the diffusibility of a water soluble superphosphate, and it is held that when rain falls after an application of such material, it distributes the phosphoric acid through the soil more perfectly than by any other method. The commercial value of superphosphate is, therefore, fixed in those countries upon the percentage of phosphoric acid which is soluble in cold water, and little or nothing is allowed for that portion which it may contain in the "reverted" or water insoluble form. In this country, however, it has been conclusively shown by practical work that this very diffusibility of soluble phosphates ensures their rapid precipitation and reversion in the soil, and that this of itself proves "reverted" phosphate to be the true and only food for the plants. We therefore, accord to it the same commercial value as we do to water-soluble phosphate, and although our staple commercial grade of superphosphate, like that of England, France, Germany and Belgium, is from 10 per cent. to 13 per cent. of soluble phosphoric acid, we differ from those countries in that we are willing to accept a portion of that solubility in citrate of ammonia which dissolves "reverted" phosphates.

The persistent refusal by foreign chemists to recognize anything but water-soluble superphosphate, naturally causes the English and German manufacturers to demand a very low percentage of iron and alumina in their raw material. I say naturally, because it has been very clearly shown that when mineral phosphate is attacked by sulphuric acid, free phosphoric acid is formed, and that after a little while this commences to react upon any undecomposed material, and first of all upon the iron and alumina.

The insoluble compounds thus produced, cause a great loss of phosphoric acid to the manufacturer of water-soluble goods, and the custom of appraising the raw material according to its percentage of iron and alumina as well as its contents in phosphate of lime, hence becomes perfectly rational. From the commercial standpoint, every part of either iron or alumina present in raw phosphate will prevent the solubility of two parts of calcic phosphate in the mixing process, and there being no mineral phosphates absolutely free from these impurities, the European manufacturers have established a maximum standard of three per cent. as the limit of them to be tolerated without allowance. When the amount present exceeds this limit, they deduct the excess in the proportion of 2 to 1 as against the phosphate of lime.

Supposing for example, that a shipment turned out upon analysis to contain seventy-eight per cent. of phosphate and three per cent. iron and alumina, the buyers would pay for each unit of phosphate without any reduction, but if the iron and alumina attained say four and one-half per cent., they would claim an allowance of three units of phosphate of lime and would only pay for seventy-five, instead of seventy-eight per cent., of the latter. The urgency for the most accurate analysis of all phosphate that is shipped abroad, being under these circumstances amply demonstrated, it is a fact to be regretted that up to the present time such accuracy has not been attained, and that the results of foreign buyers' chemists are anything but concordant with those of our producers' chemists on this side.

To the uninitiated this is an unaccountable fact, and it is all too commonly explained by the vulgar conclusion that analytical chemistry is neither reliable nor exact, and that it cannot in practice, substantiate scientific theory.

Why, it is asked, should the chemist, in the South—who is perfectly conscientious and has no interest to deceive—differ materially in his findings from a chemist, equally but no more honest and trustworthy, working at the East or North.

Nothing could cast a greater aspersion on the highest of professions than this state of affairs, and yet nothing on earth could be more easily and perfectly remedied. All that is necessary is for the chemists to come together and agree upon certain methods of sampling, and to invite purchasers and sellers of phosphates and manures to regulate their settlements on the basis of a prescribed analysis. In this manner all divergency of results should disappear, and, all other conditions being equal, any further discrepancies would be attributable only to incompetency or bad faith. The chemist's hand, is, of course, not always steady, nor is the eye always accurate, and while we are liable to physical defects and weaknesses, we shall never be free from mistakes; but it is nevertheless a fact which has forced itself upon all thinking men, that uniformity in manipulation is the prime factor in the attainment of uniform results, and nowhere is such uniformity a *sine qua non* as in the labor atory.

In my own practice I have used a method of determining the percentage of total iron and alumina in any given sample of mineral phosphate, which has been submitted to the most elaborate and painstaking investigation and comparisons by my associate Dr. L. Saarbach.

Its results seem to accord very closely indeed with those of the most prominent English and German chemists, and for this reason I take the liberty of presenting it here in the hope that its adoption may become general in commercial laboratories.

Two grammes of dried ore are very accurately weighed out and placed in a porcelain dish with twenty cubic centimeters of hydrochloric acid. The dish is placed upon a hot iron plate, covered with a watch-glass, and the contents are allowed to slowly evaporate to dryness, care being taken to avoid any spurting and consequent loss. As soon as it is quite dry, the residue is moistened with pure nitric acid in order to oxidize the iron present, and again evaporated to complete dryness. The dish is now allowed to cool and the residue is well stirred up with twenty cubic centimeters of pure hydrochloric acid, and allowed to stand for ten minutes in a warm place until it is quite disintegrated. The acid is then diluted, the whole is filtered, and the dish and the filter are very carefully washed until the filtrate measures 250 cubic centimeters. The residue on the filter must be quite white after calcination. Half of the filtrate (125 cubic centimeters) is now made distinctly alkaline by the addition of ammonia and just sufficient acetic acid, pure and concentrated, is stirred into it to produce distinct redness on very sensitive litmus paper. After being allowed to stand until perfectly cold the mixture is filtered and the beaker and residue are very carefully washed.

The substance on the filter is now dissolved by a little hot fifty-per-cent. solution of hydrochloric acid; the filter paper is washed until the wash water has a neutral reaction and the filtrate is made up to about 125 cubic centimeters. A few drops of sodium phosphate solution are now added; the liquid is then made alkaline with ammonia in slight excess; and after being made sufficiently acid with pure concentrated acetic acid as in the first operation, is well stirred up, and again allowed to stand until absolutely cold. It is then filtered on an ashless filter, and the filter is well washed with boiling water.

When the washing is complete, the filter is placed in the oven and dried, after which it is calcined with its contents; placed in the dessicator, and, when cold, the residue is weighed as phosphates of iron and alumina in one gramme of the material.

The weight of the combined phosphates having been carefully noted, they are dissolved in boiling dilute hydrochloric acid and the solution is filtered into a 100 cubic centimeter flask and washed up to the mark.

No residue should remain on the filter save perhaps a speck or two of carbon resulting from the recent incineration. In one-half of the cooled filtrate, the phosphoric anhydride is determined by the official molydate method. The resulting magnesium pyro-phosphate ($Mg_2 P_2 O_7$) is calculated to phosphoric anhydride ($P_2 O_5$) in one gramme of the combined phosphates by the factor ·6396.

The remaining half of the filtrate is warmed with a small piece of zinc in a flask fitted with a bunsen valve. When the iron is completely reduced and gives no trace of pink coloration with potassium sulphocyanate, the liquid is cooled, about one gram of magnesium sulphate is dissolved in it, and is then titrated with $\frac{1}{50}$ N. permanganate solution, every cubic centimeter of which equals ·00080 ferric oxide.

Two out of three constituents of the mixed phosphates having been thus accurately determined, the third, which is the alumina, is easily arrived at by difference.

Within the past few years, the rapid development of the fertilizer industry has led to the introdroduction of a concentrated material known as "High-grade-supers," which is made to contain about forty-five per cent. of phosphoric anhydride (P_2O_5) in a "water" and "citrate" soluble form, and which should in my opinion soon entirely supplant the weaker "supers" in general use. The plan upon which it is produced is perfectly scientific and rational, since it consists in dispensing with oil of vitrol and using in its place phosphoric acid as the solvent of the raw phosphate.

I have mentioned that in the manufacture of superphosphates as now carried out, the desired solubility, either in water or in citrate of ammonia, is attained at the cost of doubling the bulk of the raw material by the addition of sulphuric acid, which practically serves no other purpose and has no other value than that of a dissolvent. If such raw material, therefore, contain sixty per cent. of tricalcic phosphate, the "super" can only contain thirty per cent., and this, from the agricultural consumers standpoint, is certainly an anomaly, and, apart from any question of solubility, must remain so for two reasons:

(1) A ton of sixty per cent. phosphate of lime, finely ground, but insoluble in water or citrate of ammonia, can be purchased at some central point for, say $10.

(2) A ton of superphosphate, containing only thirty per cent. phosphate of lime, cannot be purchased at the same spot for less than $15.

In the one case, freight is paid upon only forty per cent. of waste material, whereas in the other, it is paid upon seventy per cent. of practically valueless matter.

That a legitimate profit should attach to the manipulation of an inert, and its transformation into an active body, is beyond question, but I cannot see why such enormous and unreasonable benefit should be derived from the trade in fertilizers by the railroad companies. If it were for no other object therefore, than the reduction of such detrimental freight charges to a minimum limit, I think it is well worth while to consider briefly the practicability of superseding the old method of manufacture.

The reactions involved in the process of superphosphate mixing have served to demonstrate that the cheapest and best known method of making liquid phosphoric acid from calcic phosphates, is by driving it from its combination with lime by means of the stronger oil of vitriol, and by utilizing many low-grade phosphates which now, for lack of a sufficiently cheap freight, have practically no market value. The only essential conditions to the manufacture are:

(*A*) That the material used shall contain a minimum of carbonate of lime, in order that no unnecessary excess of the sulphuric acid be required for its decomposition.

(*B*) That it shall contain as small a percentage as possible of any combination of iron and alumina, since both of these bodies contribute to the formation of a gelatinous mass that seriously interferes with the course of the operations.

If the exact chemical composition of the raw phosphate is known, the quantity of sulphuric acid necessary to insure the desired dissociation of all the phosphoric acid from the various bases present is very readily calculated.

The operations are conducted in large tanks made of suitable wood, lined with lead and provided with agitators The required quantity of sulphuric acid, say, for example' 2,000 pounds of 50° B. strength, is mixed in each tank with sufficient water to reduce it to a density of 14° B The agitators being in active motion, a sufficient quantity, say, 2,000 pounds of finely ground phosphate, is slowly added to each tank and stirring is continued for five hours, open steam being occasionally blown in by an injector through the side of the tank in order to keep the mixture quite hot.

When the five hours have expired, the cream from each tank is run off into filters made from large wooden vessels lined with lead and provided with false bottoms, where the hydrated sulphate of lime separates from the solution of phosphoric acid. The latter passes through the filter as a bright straw-colored fluid, of a gravity which, commencing at about 12° B., gradually becomes reduced by careful washing to 1° B.

The exercise of ordinary care and precautions prevents all cracks from being formed on the surface of the gypsum contained in the filters, and the lixiviation of the mass is stopped directly the gravity of the filtrate reaches 1° B. The hydrated sulphate of lime is now raked together into the center of the filters to drain, and is finally carried to the dump, while the last runnings from the filters, which are too weak for economical concentration, are used to dilute the strong sulphuric acid required for subsequent operations.

The filtered phosphoric acid liquor is pumped into an elevated tank, and thence it runs by gravitation to a series of leaden evaporators of any convenient form of construction, heated either by direct fire from the top or from the bottom, or by waste steam from boilers.

During the progress of the evaporation the acid solution practically deposits all its sulphate of lime, and it finally attains a density of about 45° B. At this strength it should contain about forty-five per cent. of phosphoric anhydride, with only a mere trace of lime, magnesia, and iron and alumina, and is now ready for use in place of sulphuric acid in the manufacture of soluble and assimilable phosphates. Its mixture with the raw phosphate can be effected in the usual superphosphate mixers, on the same system of calculation and by the same method of manipulation as are now used with oil of vitrol, and it very soon sets into a porous mass, which, although not very dry, is sufficiently stiff to be easily dug out. This mass is cut up into pieces of reasonable size and dried by hot air, in any form of shed that will facilitate effective and rapid work. Directly it is sufficiently dry for the market, it is put through a disintegrator and filled into bags.

If you will compare this material with our present staple superphosphate, which barely contains the equivalent of thirty per cent. of bone phosphate of lime made soluble, you will find that, in addition to its lower manufacturing cost, it contains the equivalent of ninety-nine per cent., or more than three times as much bone phosphate of lime, made equally as soluble and available. It could, therefore, be distributed at an economy of two-thirds of the freight now actually paid for useless material, and you will agree with me that this is a consideration of the highest consequence, since the world must have phosphate, and since our raw material, while it is of the best quality known, is confined to an area somewhat remote from the large mass of consumers.

The present results of phosphate mining enterprises have been very disappointing and discouraging, but I think that this should only spur us on to exercise all our ingenuity in order to make our products more available for the world's needs. As the farmers become more enlightened they will eagerly seize all means of wealth that can be readily and cheaply brought to their doors, and will be only too ready to apply to their impoverished fields the sustenance that phosphate will impart.

I do not consider that any more important duty rests upon our agricultural chemists than that of disseminating practical scientific knowledge, and of stimulating the application of that knowledge for the benefit of exhausted hands. This mission will not merely prove commercially profitable from the standpoint of manufacture and trade, but will at the same time fully satisfy all the demands of philanthropy; for, as Dean Swift has said: "Whoever can make two ears of corn, or two blades of grass, to grow upon one spot of ground where only one grew before, will deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together."

THE LAW OF INVENTION.*

By Horace Pettit, of the Philadelphia Bar.

LECTURE I.

Members of the Institute, Ladies and Gentlemen:—The race of inventors is a new race. As a race it may be said to date its existence and origin from the beginning of the nineteenth century. Each century, as it rolls around, becomes known and noted for one thing more than another, and goes down to history having attached to it some special characteristic. Prior to the beginning of the present century there was no race of inventors; a few scattering progenitors existed through the earlier centuries, plying a desultory kind of a trade, securing for their efforts sufficient discouragement and expressions of contempt and ardordampening receptions to have extinguished the brightest genius. The race was only commencing to develop when Watt produced his engine. He was a curiosity. Iconoclasts, history shows us, were always deemed cranks. For declaring that the world moved, Galileo was convicted in 1633 of heresy. Men who did or declared anything out of the usual recognized order of things were considered to be in league with the devil. Had not Ferdinand and Isabella been in advance of their times, the World's Fair celebration of the four hundredth anniversary of the discovery of America would probably not have been held until a much later date.

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*Two lectures delivered before the Franklin Institute, November 10, 1893.

Start at the beginning of this century and go back, decade by decade, century by century, and we will find only a scattering few who rose to the dignity of inventor—and they decreased as the square of the distance. What was invented or discovered by the early forefathers of invention was not then followed up nor developed. The inventors died and passed away, and with them their discoveries or theories—there was no one to follow them up. As the centuries rolled on, however, greater development was discernible in isolated instances.

The Chinese were far ahead of their day and generation in the world of discovery and invention in centuries gone by; but the Chinese race is, and always has been, peculiarly constituted—the Chinese did not, and do not, develop—they copy—they do not progress. Dr. Strong, in his recent work, "The New Era" says: "It would seem as though the Chinese were all run in the same mould and each generation were a weary repetition of the preceding. There is a uniformity which is favorable to far-reaching organization, but fatal to individuality; and where there is no individuality there can be no progress. China has stood for many years with her back to the future." There was no development here. But development did come slowly, however, to other countries. The knock which Sir Isaac Newton is said to have received on the head by the falling apple seemed not only to stir him, but also to set others to thinking. Here was a natural law which had existed since the creation, and yet it seems not to have been fully realized and appreciated until about 1666.

Is it not strange that, although all the laws of nature as they exist to-day have existed since the beginning of time, it was not until this century that they have been measurably understood, or the powers and forces through which they found expression, applied practically in an advanced degree to commerce and the arts? Given the dissemination of knowledge through the medium of the printing press, the practical application of steam for motor purposes, the development of metallurgical processes and the harnessing of electricity to instant message transmission and to the production of power, and we have a state of affairs which renders possible the development of the inventive faculties at a rate which increases with astonishing rapidity. Its development may be likened to the increasing velocity of travel of a falling body.

To the latter half of this century has been reserved the distinction and honor of achieving more in the line of invention and discovery than all the ages of past history combined. This may be truly said to be the "Era of Invention."

To past centuries the word "invention" had little meaning; to our contemporaries it is a word of the most significant importance. To consider the subject practically, we must consider it from its legal standpoint. It will be appreciated that the time allotted to two brief papers must necessarily involve a somewhat cursory consideration. A subject, therefore, which involves so much can only be briefly touched upon, and only in some of its principal branches. The question, "What is Invention?" will have to be considered somewhat at length, and will occupy the larger portion of this evening's paper.

SOVEREIGN RIGHTS.

It will be unnecessary to consider the common law as it existed in England or in this country prior to any legislative enactment relative to patents for inventions, except, perhaps, in a most cursory manner, as no right of property existed in an invention or discovery at common law. There is no doubt that at common law the prerogative existed in the king to grant to his subjects protection, at least for a limited period of time, for their inventions. But no *right of property* in an invention existed at common law. Previous to legislative enactment—without the special exercise of the prerogative on the part of the king—the inventor or discoverer had no right of property in his invention or discovery, and after he had once enlightened the public, or any individual, as to its construction or existence, he was powerless to prevent others from manufacturing, selling or using to any extent that they saw fit. The prerogative of the king was, of course, only exercised at his will, large sums being frequently demanded as the price of its purchase.

Prior to 1623, the prerogative of the sovereigns of England in granting monopolies of all kinds had been abused to a very large extent for the purposes of raising revenue to meet the expenses of the crown. This right, in the hands especially of an unscrupulous sovereign, worked disastrous results upon trade and commerce; the favored few secured monopolies in particular lines of business, to the exclusion of all others; shops and factories, which, perhaps, had been established after many years of arduous toil, and by the outlay of large sums of money, were in a day closed down by the seal of the sovereign placed upon a piece of parchment, granting to one favored courtier or subject the exclusive right to engage in that particular line of trade or branch of commerce. From about 1261 to the time of the reign of Edward VI (1551), the commerce of England was almost entirely in the hands of foreigners—especially those from the Hanse towns, or Easterlings, as they were called, to whom Henry III had granted special privileges and erected into a corporation in order to induce them to settle in London. During this period they were maintained and protected by the crown to the exclusion of all others. Hume, Chap. xxxv, says: "So ignorant were the English of commerce, that this company, usually denominated the merchants of the 'stil-yard,' engrossed even down to the reign of Edward VI almost the whole trade of the kingdom." Naturally, great abuse of their privileges arose, to the great detriment of the English citizens. In A. D. 1551, the privileges were very much restricted, and thereafter the industries of London and England began to thrive in the hands of the citizens. But other abuses began to creep in which were equally as injurious to trade generally as when it was the monopoly of the foreigners.

The royal prerogative was given or bartered for mercenary purposes, and the bulk of the trade of England began to be absorbed by the few. (Robinson, on Patents, vol. 1, p. 6.)

The reign of Elizabeth was notorious. The necessaries of life were monopolized, under royal grant, by a few; salt, for instance, which had been sold at six pence per bushel, was raised to fourteen shillings; oil, starch, vinegar, paper, were controlled by the monopolists, who had the arbitrary right thrown in with the grant to search stores and private property where they suspected any alleged infringing goods to be stored. (Hume, c. xliv.)

We talk about the greed of corporate monopolies and trusts of the present day, but their attempts, let me say, have been comparatively futile as compared with those of our illustrious ancestors of 1600. Even after James I tried to alleviate the matter by rescinding the rights of the monopolies under grant, a gigantic trust was formed consisting of prominent merchants of London, who combined together to control the foreign trade, raising or lowering the prices of imports at will.

If any of our Sugar or Standard Oil Trusts should have attempted to apply for a patent to protect their processes of dealing, it is quite clear their claim would have been invalidated by the citation of this anticipating reference. If we only reflected we would ofttimes be very much chagrined and taken aback by discovering that in many things we are but weak imitators of the virtues and vices of our illustrious ancestors.

Before Parliament saw fit to take any action in the matter of these abuses of the royal prerogative, private subjects carried the question before the court of the King's Bench, in the shape of an infringement suit, by way of defence. It was not contended in the suit referred to that the king had not the right to grant exclusive privileges for limited periods of time, where the grantee, by his own charge and industry, or his own wit or invention, brought any new trade into the realm, or any engine tending to the furtherance of the trade that never was used before—and that for the good of the realm—in such cases it is clear that the king could grant a monopoly patent for some reasonable time until the subjects learned the same, in consideration of the good that he brought by his invention to the Commonwealth; otherwise not.

The case referred to is that of Darcy *vs.* Allin (1602), (Noy, Rep., 173), (Coke R., 84 b.). This case, as well as that of the subsequent case of the cloth-workers of Ipswick, which are referred to in most of the text-books (1615, Godbolt, 252; 1 Abb. P. C.) were both cases in the King's Bench where the patents or grants of monopoly were defeated, and the validity of the letters-patent was denied.

The case of Darcy *vs.* Allin was an action on the case upon a grant made by Queen Elizabeth in the thirtieth year of her reign, to one Ralph Bowes, for the exclusive privilege of making, importing and selling playing cards for the period of twelve years, which had subsequently been extended to the plaintiff, Darcy, an assignee of Bowes. Darcy brought the suit against Allin to restrain him from manufacturing playing cards. It was not contended that Bowes, the original grantee from the Queen, was the inventor of playing cards, but that under the grant made to him, by virtue of the Queen's prerogative, he had the exclusive monopoly of the trade in playing cards for the period stated. In other words, it was not contended that Bowes conceived anything, or discovered or invented anything, which had not been known before. The defendant denied the right of the Queen to make such an exclusive grant, and contended substantially that the liberties of the subjects in this regard were preserved and maintained to the subjects by Magna Charta.

The general question, however, of prior knowledge or use was also discussed. It was contended, also, that even where letters-patent had been granted by the sovereign for alleged inventions they were invalidated when it should be shown that the particular article protected had been known and used in the kingdom before, as where a monopoly patent was granted in ninth Elizabeth to a Mr. Hastings for making frisadoes, such as it was averred had never been made in England before, but which he had introduced from Haarlem and Amsterdam, beyond the seas, a penalty being provided in case of any infringement thereof. The defendant in this case escaped, having shown that baize, very like Mr. Hastings' *frisadoes*, was made in England before the date of Mr. Hastings' patent. In another case, that of a monopoly patent granted for knives with bone hafts and plates of lattin, to Mr. Matthey, of Fleetbridge, he being alleged to have brought the same from "beyond the seas." Here also, other knives, so like Mr. Matthey's, were shown to have been used in England before, that the defendants were not restrained. Humphrey's monopoly patent for a sieve, or instrument for melting lead, was judged invalid on the ground that it had been used before in Derbyshire and at Mendiff in the West Country.

Darcy *vs.* Allin was decided in favor of the defendant and against the right of the sovereign to grant an exclusive monopoly for anything other than an *invention* or *importation*, as also in the cloth-workers' case before cited.

STATUTE OF MONOPOLIES.

This evil of monopolies becoming more and more apparent, the matter was substantially cured and corrected, at least as far as possible, in 1623, by the Statute of Monopolies, 21 James I, (c. 3, s. 6), whereby it was enacted that all monopolies were contrary to the laws of England, and were, and should be, null and void.

Section 6, however, contained an apparent exception as follows, viz.: "Provided also, and be it declared and enacted: That any declaration before mentioned shall not extend to any letters-patent and grants of privilege for the term of fourteen years, or under, hereafter to be made of the sole working or making of any manner of new manufactures within this realm, to the true and first inventor and inventors of such manufactures, which others, at the time of making such letters-patent and grant, shall not use, so as also they be not contrary to the law nor mischievous to the State by raising prices of commodities at home or hurt of trade, or generally inconvenient; the said fourteen years to be accounted from the date of the first letters-patent or grant of such privilege, hereafter to be made; but that the same shall be of such force as they should be, if this act had never been made, and of none other."

The effect of this clause of the Statute of Monopolies was not to restrict the king's prerogative, as it existed prior to the passage of the act in relation to patents for inventions, but to define his right to grant patents for the term of fourteen years, for the sale, making or working of any manufacture not hurtful, and "shall be of such force as they should be if this act had never been made, and of none other."

Mr. Curtis, in his introduction to his work on the "Law of Patents," says, in his preliminary observations:

"A patent for a useful invention is not, under our law, or the law of England, a grant of a monopoly in the sense of the old common law. It is the grant by the government to the author of a new and useful invention, of the exclusive right, for a term of years, of practising that invention. The consideration for which this grant is made by the public is the benefit to society resulting from the invention; which benefit flows from the inventor to the public in two forms, *first*, by the immediate practice of the invention under the patent; and, *secondly*, by the practice of the invention, or the opportunity to practise it, which becomes the property of the public on the expiration of the patent."

It is unnecessary here, in this brief paper, to further consider the Statute of Monopolies, the cause for its passage, or its effect. The subject is elaborately considered in numerous text-books upon patents, and notably so in "Robinson on Patents," Vol. I. Suffice it to say, that Sec. 6 of this Statute determined by special grant the right of the inventor to protection for his invention for a limited period of time at the hands of the sovereign.

THE LAW OF PATENTS IN THE UNITED STATES.

Most civilized countries have made provision for the protection of inventors in their inventions. This moral right of the inventor of exclusive property to his invention for a limited period of time, and the benefit which is to be derived by the public by such stimulus to invention, has been fully recognized.

In the United States the inventor's right is now based solely upon the Constitution of the United States and Federal legislation. I do not mean to say that the individual States have no right to grant patent privileges to their citizens, or to those residing within the State; on the contrary, there is high authority for the proposition that the individual States have still this right should they desire to exercise it.

The Federal Government has only the powers and privileges which have been granted it by the individual States or by the people, which powers and privileges are derived from the Constitution of the United States.

The Constitution, Article I, Sec. 8, provides that "The Congress shall have power . . . to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

In the case of Martin *vs.* Hunter's Lessee (1 Wharton R., 304), it was held: "The Government of the United States can claim no powers which are not granted to it by the Constitution; and the powers actually granted must be such as are expressly given, or given by necessary implication." This doctrine does not apply to the independent States. Their powers are sovereign powers, but limited by the powers which they have conferred upon the Federal Government through the Constitution.

Daniel Webster said, with much force: "Our Constitution is one of enumeration, and not of description."

This grant of power by the States to the Federal Government, it is contended by Chancellor Kent, does not, by the terms of the grant contained in the Constitution, confer or imply an *exclusive* grant therefor; that is, it does not confer such an exclusive grant as to preclude the individual States from granting through the proper channel protection to inventors, if the State should see fit to do so.

Bearing upon this question of the concurrent right of individual States to grant patents for inventions, Chief Justice Kent, in the case of Livingstone and Fulton *vs.* Van Ingen (1812) (9th Johns., 507), held as follows:

"If the grant is not inconsistent with the power of Congress to regulate commerce, there is as little pretence to hold it repugnant to the power to grant patents. That power only secures, for a limited period of time, to authors and inventors, the exclusive privilege to their writings and discoveries; and as it is not granted by exclusive words to the United States, nor prohibited to the individual States, it is a concurrent power which may be exercised by the States in a variety of cases, without any infringement of the Congressional power. A State cannot take away from an individual his patent right and render it common to all citizens. This would contravene the Act of Congress, and would be therefore unlawful."

We should want no better authority than that of Chancellor Kent. Were the authority less eminent, we should accept the doctrine with much caution.

SECTION 4886.

It is unnecessary to follow this question of State rights further; let us proceed to a more intimate consideration of the law and the cases. By the Constitution the power was given to *Congress;* it was incumbent upon Congress to act.

The acts of Congress passed since the date of the Federal Constitution relative to patents are numerous. These numerous acts we will not pause here to separately consider, but must pass immediately to the law as it is contained in the Revised Statutes of the United States.

Section 4886 of the Revised Statutes of the United States is as follows:

"Any person who has invented or discovered any new and useful art, machine, manufacture or composition of matter, or any new and useful improvement thereof, not known or used by others in this country, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, and not in public use or on sale more than two years prior to his application, unless the same has proved to have been abandoned, may, upon payment of the fees required by law, and other due proceedings had, obtain a patent therefor."

This brief section embodies substantially the backbone of the patent law of the United States as it exists to-day, and yet these few lines are required to be interpreted and re-interpreted in almost every suit litigated involving the patentability of an invention. Volumes of decisions have been written upon it, and volumes will continue to be written so long as it or any like statute exists.

It may safely be said that in no branch of litigation does each case "stand upon its own bottom" so thoroughly and so completely, and require such independent review as do the cases involved in patent litigation.

This brief section absolutely defines who is entitled to a patent, and it defines what things are the subjects of patents, which no court in the United States can gainsay. But the courts interpret. Many cases are on the border line, which renders just interpretation frequently exceedingly difficult.

What is that "border line" of invention upon which so many litigated patents serenely rest? It is as marked and well defined as that imaginary line drawn in the fair sex, on the one side of which the girl is a blushing bud, on the other a full-blown rose. Where are you going to draw the line of demarcation? Ask of the highest Court of Appeals, and perchance it will give you no fixed infallible rule. Know that line, then you will know what is and what is not *patentable invention.*

WHAT IS PATENTABLE INVENTION?

I desire at this point to say that even now in *doubtful* litigated patents, the practical commercial results of the invention serve as a powerful guide to the courts, as it has done in the earlier times, in determining the question of *patentability*. A careful examination of the cases bears out this view.

Where a mere doubt exists at the time of application regarding the novelty and patentability of an invention, it is generally resolved, as it should be, in favor of the applicant, and the courts, when subsequently called upon to pass upon such patent, will, as they should, be considerably guided, where such a doubt as to patentability still exists, by the fact that the invention in question has proved commercially successful.

THE TELEPHONE CASES.

As a usual rule, however, in the class of cases just referred to, it will be found that where an invention has proved successful commercially, there is some *inherent reason* for it residing in the invention itself. This may be illustrated, for instance, by the celebrated telephone cases, where a mass of alleged anticipatory testimony, some of it very strong, was produced. It is true that the credibility of some of the testimony was very much doubted by the court, but Mr. Bell had in his favor throughout the whole proceedings the fact that he had described a successful operative means of transferring to, or impressing upon, an undulatory current of electricity, the vibration of air produced by the human voice in articulate speech, in such a way that the speech was carried to and received by a listener at a distance on the line of the current. Never before had such an invention been given to the public; it was one of the greatest inventions of the age, and naturally it would have taken very strong evidence of anticipation to have defeated his patent (American Bell Telephone Cases, 126 U. S., 863).

The Bell Company rested their entire case upon the fifth claim of the Bell patent, which is as follows: "The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth."

It is interesting to note that when Bell applied for his patent he had never actually transmitted telegraphically-spoken words so that they could be distinctly heard and understood at the receiving end of his line; but as stated by Mr. Chief Justice Waite, in delivering the opinion of the court, "In his specification he did describe accurately, and with admirable clearness, his process; that is to say, the exact electrical condition that must be created to accomplish his purpose; and he also described, with sufficient precision to enable one of ordinary skill in such matters to make it, a form of apparatus which, if used in the way pointed out, would produce the required effect, receive the words, and carry them to and deliver them at the appointed place. The particular instrument which he had and which he used in his experiments did not, under the circumstances in which it was tried, reproduce the words spoken, so that they could be clearly understood; but the proof is abundant, and of the most convincing character, that other instruments, carefully constructed and made exactly in accordance with the specification, without any additions whatever, have operated and will operate successfully."

It will thus be seen that, although Bell did not give to the public at the date of his application for a patent, a commercially operative device, and never up to that time had constructed one himself, he did, nevertheless, describe and claim such a device in his application as would enable others skilled in the art to make a successful operative commercial device. Perhaps it may safely be said that at the date of Bell's application he had not been as successful in his actual experiments as some of those who had experimented before him, but they had never completed, either in an actual device, or upon paper, the invention to the extent to which Bell had perfected it.

Mr. Chief Justice Waite said, *inter alia:* "Some witnesses have testified that they were unable to do it (construct an apparatus from Bell's patent); this shows that they, with the particular apparatus which they had, and the skill they employed in its use, were not successful; not that others, with another apparatus, perhaps more carefully constructed, or more skilfully applied, would necessarily fail. As was said in Webster Loom Company *vs.* Higgins (105 U. S., 580,586), 'when the question is whether a thing can be done or not, it is always easy to find persons ready to show how not to do,' if one succeeds that is enough, no matter how many others fail. . . . The law does not require that a discoverer or inventor, in order to get a patent for a process, must have succeeded in bringing his art to the highest degree of perfection. It is enough if he describes his method with sufficient clearness and precision to enable those skilled in the matter to understand what the process is, and if he points out some practicable way to put it into operation. This Bell did."

EDISON LAMP.

Another illustration which may be used in this connection is the Edison incandescent electric lamp (U. S. Patent No. 223,898, Jan. 27, 1880). This has gone most largely into commercial use, and there are now few small towns in the United States, as well as in Europe, which have not installed some of these incandescent electric lamps.

Mr. Edison had his patent sustained in two or three of the Circuit Courts of the United States (Edison Electric Light Company *vs.* U. S. Electric Lighting Company, 47 Fed. Rep., 454, Dist. N. Y., affirmed, 52 Fed. Rep., 300; Id. *vs.* Beacon Vacuum Pump and Electrical Company, 54 Fed. Rep., 678, Dist. Mass.) In one or two of the later cases a new defence, in the shape of an alleged anticipation of the Edison patent has been presented, and very elaborately, in the case of the Edison Electric Light Company *vs.* The Columbia Incandescent Lamp Company (65 Off. Gaz., 133, East Dist. of Missouri) on motion for preliminary injunction. In this case the court refused the preliminary injunction. Without having had the pleasure of examining the evidence presented upon the motion for preliminary injunction, I understand, from the data given in the report, and from other unofficial data, that the defence alleged is, substantially, that one Henry Goebel, a German by birth, came to this country prior to 1854, having acquired some knowledge of electricity abroad. He opened a small shop in the lower part of New York City and plied a desultory kind of a trade in repairing watches, telescopes and optical instruments; that before coming to this country he had become in some manner associated with a gentleman familiar with electricity, who suggested to him the idea of producing light by means of electricity through the medium of a film to be rendered incandescent in a vacuum bulb; and that after opening his shop in New York he spent some of his leisure time in carrying out this idea, and did make, as early as 1854, out of fine strips of bamboo, films which he encased in a glass globe rendered air-tight, and by connecting a current from a battery, or other source, produced what was substantially an incandescent light, his lamp being different in form, but in all essential features the same as those now in general use.

Goebel exhibited this in his shop window as a matter of curiosity, and also on the streets of New York, at the base of a large telescope, which he took around in the evenings to allow passers-by, at a small price, to view the stars; the incandescent lamp here also operated as a curiosity, or means of attracting attention to his telescope. It appears that Goebel has recently made several lamps of the form and with the material and tools formerly used by him. "These lamps," said Judge Hallett, in the Missouri case, "were tested by men of skill and experience in such matters, and they were found to be reasonably effective. They are not so good as the lamps in common use; but they can be operated and they give reasonable service in time and capacity of light."

The Judge did not appear to think Goebel's testimony to be at all improbable, and that it was supported at many points by witnesses of good repute, who spoke with precision and apparently with deliberation.

This case is peculiar. The invention might have been for practical purposes completed by Goebel in 1854—we may say perfected—and yet not have gone into general use or have been taken up by the public because it required something outside of itself to bring it into general use—a commercially practicable current generator, which was not perfected until a much later date. If defendant's contention is correct, Goebel's lamp of 1854, applied to the present dynamo, would have successfully operated, and containing, as contended, all the essential features of the claim of the Edison, 1880, patent, would defeat the claim.

If in this case defendant's contention is correct that the Goebel lamp did contain all the essential elements of the Edison lamp, there being no substantial difference between the two, the fact of Edison's commercial success, and of supplying the public want, would not enter into the consideration of the case, as this was due, not to perfection or change in invention, but to an *extraneous fact*, namely, the coming into existence of the commercial dynamo. On the other hand, it might be urged, why did Goebel not bring forth his invention immediately upon the introduction of the commercial dynamo, and not wait until thirteen years after Edison secured his patent before the Goebel claims should be pressed. Numerous explanations might be made to this contention. If the testimony to be produced upon final hearing substantiates that which appears to have been produced by affidavits upon the motion for preliminary injunction, it would certainly look as though Mr. Edison would be deprived of the credit of being the inventor of the incandescent lamp. All engaged in patent practice, however, know that it is easier to defeat a motion for preliminary injunction and cast the time-worn "reasonable doubt" upon validity, than to ultimately sustain it upon final hearing.

Section 4886 says "any person" is entitled to a patent who has invented or discovered, etc. This leaves no doubt that any one who answers the other requirements is entitled to a patent, be the inventor native or foreign born, black or white, adult or minor, male or female. It was formerly not so in the United States. Aliens were discriminated against;

but through sundry acts of Congress the *alien* was placed upon a par with the native born. Should an inventor die before obtaining protection by letters-patent, his invention may be patented by his executors or administrators, with full protection of his rights.

The wording of this section of the act is very plain, but the adaptation of it to the particular cases as they arise is most difficult. The section of the act says: "Any person who has invented. or discovered, any new and useful art, machine, manufacture or composition of matter," etc., is entitled to a patent. The section of the act does not say what invention is; that question is left to the Patent Office in the *first* instance, and to the courts *ultimately*. As there appears to be no fixed rule by which invention is to be determined, it is one of the most difficult questions which a patent attorney has to solve, to successfully decide, especially in *border line* cases, what is, and what is not, invention; the court has the last guess.

Mr. Walker, in his work on patents, section 24, says: "It is seen to remain true that the ideal line which separates things invented from things otherwise produced has never been completely defined or described. There is no affirmative rule by which to determine the presence or absence of invention in every case" (citing Dunbar *vs.* Field Tack Co., 4 Ban. and Ard., 519).

Robinson on Patents, Vol. I, section 59, says it is perhaps incapable of exact definition, and the line between it and what the patent law regards as a mere imitation is very difficult to draw.

Mr. Edward S. Renwick, who may be said to have had the largest experience of any man (living or dead) as an expert in patent cases, in his recent work, entitled, "Patentable Inventions," says, p. 1, section 2: "As to what constitutes invention the following dictum was pronounced, in 1880, by the United States Supreme Court (Pearce *vs.* Mulford, 102, U. S., 112, 26, L. ed. 93): 'but all improvement is not invention and entitled to protection as such. Thus to entitle it, it must be the product of some exercise of the inventive faculties.'" "What these faculties are," says Mr.

Renwick, "or how they are to be distinguished from the constructive faculty of the mind, is a matter that is left by the court in profound obscurity. No two persons can agree as to the line of demarcation between the two faculties, because from the variations in the characters of the minds of men, their differences in training and in experience, a change which to one mind appears to have involved the exercise of the so-called inventive faculty, is thought by another (*after* the event) to have been the result of merely the constructive faculty or of mechanical skill. Hence, to test the existence of invention by the assumption of the exercise of mental faculties by which it has been produced, and which are indefinable, amounts simply to an attempted determination of a truth by mere judicial opinion, without reliance upon evidence and without recourse to rules by which a just conclusion can be reached."

This, certainly, of itself, would leave the subject in the state of chaos. Mr. Renwick very naturally deplores this condition of affairs, viewed, as he views them, and fears that the creation of the present nine appellate courts will tend to multiply the constructions of the law as to what constitutes invention, rendering it more diverse than even heretofore, unless these courts shall decide upon *some rule* by which invention can be determined. By reason of Mr. Renwick's large experience as a patent expert and solicitor of patents (although, I believe, he has never been admitted to the bar), his opinion is entitled to much respect, and it would be with great caution that any one would attempt to criticise the views of one of his years, ability and experience. He deplores the condition of affairs in any case wherein the question of invention is decided by the *mere opinion* of the court. "Formed in every case *after the event*, the matter is at once removed from the domain of evidence and is cast upon the sea of uncertainty, where it is subjected to the varying qualities and shifting views of the minds of judges, who, however, while trained in the science of the law, have, as a general rule, no personal experience in the operation of an inventor's mind." He favors the methods of the courts in the earlier decisions, as having been guided by certain definite rules in determining this important question, while many of the later decisions of the highest court have determined the question upon mere opinion *after the event.* Mr. Renwick cites, Earl *vs.* Sawyer (4 Mason, 1), as containing a rule by which invention may be determined, viz.:

Earl *vs.* Sawyer.—A change was decided to be *new* under the patent law when it had not been known or used before. It was decided to be *useful* if it would accomplish the purpose for which it was designed, and was not noxious or hurtful.

Mr. Renwick says, p. 4: "These *two* requirements of novelty and utility are clearly susceptible of proof by evidence; and it is deducible from the earlier decisions, and those which have followed in the same line, that a change which involves those requirements is an invention within the meaning of the patent law within certain well-defined exceptions." The exceptions which he notes in Section 6 are where the changes are simple and not sufficient to involve invention, such as a *mere change* in size or degree, in proportions, of material, of location or arrangement, the mere application of an old thing to a new purpose, the mere application of an old thing to perform its usual functions with its usual mode of operation or movement, mere substitution of an old device for another, a mere duplication of old devices, a mere change of the direction of movement of a moving device, the discovery of a new property of matter. This is not saying that changes do not involve invention, but that *mere* changes, or such as are so simple as to be within the knowledge of the ordinary skilled mechanic are not invention.

It is hard to say that the rule which Mr. Renwick seems to adopt, or at least suggests as the method of determining what is and what is not patentable invention, is itself an easy rule of guidance, viz.:

Under Earl *vs.* Sawyer, *supra,* invention equals a change not known or used before (it being understood that the change is not a *mere* change of size, proportion, etc., such as noted in the exceptions referred to); and, secondly, the change must be useful, and is useful if it accomplishes the purpose for which it was designed, and not noxious or hurtful. These two requirements of novelty and utility are stated to be susceptible of proof by evidence.

This rule may be as positive, with the exceptions noted, as it is possible to formulate, but it is certainly not infallible. The exceptions themselves form such a very broad class that one or more of them are apt to enter into the consideration of almost every case where there is any doubt; and again, the exceptions to the exceptions, which are noted on pp. 5 to 40, in the cases therein cited, render the rule still more difficult of application, so that we are unwillingly obliged to agree that Mr. Walker is not far from right when he states, in his work on patents, section 24, before quoted, that the ideal line which separates things invented from things otherwise produced has never been completely defined or described. There is no affirmative rule by which to determine the presence or absence of invention in either case; and with Robinson and others, that what is invention is perhaps incapable of exact definition.

It is true the thing must be *new* and must be *useful* to constitute a patentable invention; the mere fact that it is useful does not make it *new*, but everything that is new, and is sufficiently worth fighting for, to get into the courts, is generally *useful*, and consequently this question of utility does not usually seriously hamper the judges in their decisions.

The main question is: "What is *patentable newness?*" In Earl *vs.* Sawyer (4th Mason, 1) (1825), it was held to involve invention to substitute a circular saw in the place of an upright saw in a shingle machine, the other parts remaining substantially unchanged.

This case was about as short a distance over the *border line* of invention as any case ever passed upon by the Supreme Court of the United States where the validity of the patent was sustained. The patent was issued December 28, 1822, to one Earl for a shingle sawing machine, and the only difference existing between it and the invention of a prior patent of the same inventor consisted in the substitution of a circular saw for a perpendicular reciprocating saw in the shingle machine. The two machines were the same, with this exception. It was proven that circular saws were in use before in other constructions.

This is one of those cases where the court was influenced somewhat by practical results. It was shown that while the old machine sold for $60 or $70 the new machine sold for $150 or $200.

Judge Story held: "If it is new; if it is useful; if it has not been known or used before, it constitutes an invention within the very terms of the act, and, in my judgment, within the very sense and intendment of the Legislature."

Hotchkiss *vs.* Greenwood. In the case of Hotchkiss *vs.* Greenwood (11 How., 249), the improvement consisted in making knobs of clay, or porcelain, and in fitting them for their application to doors, locks and furniture, having the cavity in the knob in which the shank is inserted, and by which it is fastened, largest at the bottom and in the form of dovetail, or wedge reversed, and secured in the knob by pouring the metal in a fused state. The claim was as follows:

"The manufacturing of knobs, as stated in the foregoing specifications, of potters' clay, or any kind of clay used in pottery, and shaped and finished by moulding, turning, burning and glazing and also of porcelain."

The Supreme Court decided the patent to be invalid; that the mere substitution of porcelain in making knobs for metal, wood, or other material did not involve invention; that the difference was merely formal and destitute of ingenuity. It might have afforded evidence of judgment and skill in the selection and adaptation of the materials in the manufacture of the instrument for the purpose intended, but nothing more.

Mr. Justice Nelson, in delivering the opinion, stated: "I remember having tried an action in the Circuit in the District of Connecticut some years since, brought upon a patent for an improvement in manufacturing buttons. The foundation of the button was wood, and the improvement consisted in covering the face with tin, and which was bent over the rim so as to be firmly secured to the wood. Holes were perforated in the center by which the button could be fastened to the garment. It was a cheap and useful article for common wear, and in a good deal of demand. On the trial, the defendant produced a button, which had been taken off a coat on which it had been worn before the Revolution, made precisely in the same way, except that the foundation was bone. The case was given up on the part of the plaintiff. Now, the new article was better and cheaper than the old; but I did not then suppose, nor do I now, that this could make any difference unless it was the result of some new contrivance or arrangement in the manufacture. Certainly it could not, for the reason that the materials with which it was made were of a superior quality, or better adapted to the uses to which the article was applied."

The case of Hotchkiss *vs.* Greenwood was not decided without dissent. Mr. Justice Woodbury filed quite an elaborate dissenting opinion, in which he stated, *inter alia:* "Now on the point as to the invention being patentable, the direction virtually was to consider it not so, if an ordinary mechanic could have made or devised it; whereas, in my view, the true test of its being patentable was, if the invention was new, and better and cheaper than what preceded. This test, adopted by the Circuit Court, is one sometimes used to decide whether the invention for which a patent has been obtained is new enough or distinguished enough from the former invention to prevent it from being an infringement, and to justify a new patent for it, and not, as here, whether it is valuable or material enough *per se* to be protected by any patent . . . but it is impossible for an invention to be merely colorable, if, as claimed here, it was better and cheaper; and hence this last criterion should, as requested by the plaintiffs, have been suggested as a guide to the jury. . . . There is a new manufacture, as here, of clay into knobs or knobs with a dovetail hollow combined with a shank. The books are full of such slight changes in structure, composition or mode of application, which were novel and better in their results and therefore upheld, and were not and could not be regarded as the *mere* application of an old machine to new purposes, besides the new material and the new mode of fastening when the results, as here, are considerably improved, they suffice to make the invention patentable. These are then all required by the strictest law, viz.: "diversity of method" and "diversity of effect" (citing Webster on Subj. Matter, Phillips on Patents, 122.)

This clearly illustrates the diversity of opinion, even among the judges of the Supreme Court of the United States, as to *what does constitute invention.* Applying one of the rules cited, it would come under one of the exceptions noted, and consequently would not involve invention, being a *mere* substitution of material. But right here the difficulty occurs in applying the rule, or exceptions, as to whether the case came within the exceptions and involved a *mere* substitution of material and nothing more. The majority of the court thought that it did, the minority thought it did not, but involved something more.

A different ruling was made in the suit upon the patent issued in September, 1848, and reissued 1861, to John Young, for a washing and wringing machine, having its rolls covered with India rubber. Rolls in like machines had been previously covered with cloth and felt, and Young's machine was the first in which the rolls were covered with rubber. This, it was held, was patentable; that it was *not a mere* substitution of material, as the rubber was impermeable to water and more elastic. All that Young did in this case was to take off the cloth or felt covering from the rolls and fasten on a rubber cover. The qualities of the rubber, which were particularly advantageous in this particular use, were not discovered by Young, but were known before; viz.: that it was elastic and impermeable to water; therefore, he cannot be said to have discovered anything. He undoubtedly made a better machine, but it might also be said, and was admitted, that the Hotchkiss knob made a better knob. The difference between these two cases may be said to reside in the fact that in the Hotchkiss patent the knob of earthenware had no function to perform which the old wooden knob did not perform, while the rubber in the Young machine had a function to perform which differed from the old rollers, though only in degree.

It is clear when the cases resolve themselves into such fine points that the court has a decided advantage over the patent attorney in that its finding is final and conclusive, while the patent lawyer's finding is merely interlocutory. One excellent test to apply to the question of invention, where a serious doubt exists, is, "does the alleged new thing fulfil useful requirements not previously met or performed, or does it perform any new and useful function in the combination in which it is employed?" Arguing back from this point, if the answer is in the affirmative, careful examination will prove that the difference or change in the new thing, although slight, is material and patentable. In the case of Foote *vs.* Silsby (1 Blatchf., 445), subsequently affirmed in the Supreme Court of the United States, 20 How., 378, the device involved consisted in a stove with its draft valve connected by two levers with two expansion rods of sheet brass; these expansion rods being brass, contracted and expanded to a greater degree than the iron of the stove; by this means the draft valve was closed and opened. Numerous devices operating in a substantially similar manner by the expansion and contraction of the different metals being differently affected by the same degree of heat were shown to have existed long prior to the date of the Foote patent, which was May 26, 1832.

Judge Nelson, in deciding the case in the court below, said, *inter alia:* "The substance of the discovery as claimed by the plaintiff, and secured to him by the patent, is the application of the principle of the contraction and expansion of a metallic rod, by the use of certain mechanical contrivances, particularly described and set forth, to the cast or sheet iron stove in common use, by which means he produces a self-regulating power over the heat of the same at any given degree of heat that may be desired within the capacity of the stove. This is the thing invented. It is, in a word, the application of a well-known principle *to a new and useful purpose;* and the question is, whether or not the patentee was the first and original inventor, or whether it was before known and in public use. Now, although it is shown (assuming for the present that we may look into the books not in evidence) that the principle had before been applied to the regulation of heat, as in the instance of Dr. Ure's 'Thermostat,' and Bonnemain's 'Heat Regulator,' and some others, yet, from aught that appears from testimony, or from any book that has been produced, the plaintiff was the first person who applied the principle to the *regulation of heat to* stoves; and for this he was entitled to a patent and to be protected in its enjoyment (citing Phillip's Patents, Chapter 7, Sec. 6, p. 101). It is not a new use of the principle as previously applied to the regulation of heat, which would not be patentable; but a new application of it by new mechanical contrivances and apparatus by means of which a new and beneficial result is produced in the use of the article to which it has thus been applied, viz.: the common cast or sheet iron stove."

Mr. Justice Nelson subsequently, in another phase of the same case, 2 Blatchf., 270, held: "Where a party has discovered a *new application* of some property in nature, never before known or in use, by which he has produced a new and useful result, the discovery is the subject of a patent, independently of any peculiar or new arrangement of machinery for the purpose of applying the new property in nature; and hence, the inventor has a right to use any means, old or new, in the application of the new property to produce the new and useful result, to the exclusion of all other means."

The cases selected and presented in considering the question of What is Invention? are those principally in which the spark of invention, if existing at all, was almost invisible. When consulted upon the question of the patentability of an alleged invention wherein the existence, or the possibility of the existence, of the exercise of the inventive faculties is not above suspicion, the attorney's mind frequently turns involuntarily to a tin box tightly closed, containing caustic alkali, and to the process of putting it up.

I refer to certain two reissue patents granted to George Thompson, one for caustic alkali enclosed in a tight metallic integument or metallic casing, and the other for the process of putting it up. The original patent upon which these reissues were granted was issued October 21, 1856.

Suit was brought against infringers at least twice, and at least twice were these patents sustained, and the infringers enjoined. The patents were represented by Mr. George Harding, one of the ablest patent attorneys of this country, and whose name is associated with more important patent suits than that of any lawyer of the century; one whom Philadelphia is justly proud to claim her own.

The validity of the patents was attacked in the case of the Pennsylvania Salt Manufacturing Company *vs.* Thomas (8 Phila. R., 144), as well as in Same *vs.* Guggenheim. In the original patent the invention was stated to consist in a new and useful mode of wrapping cakes of potash or caustic soda in air-tight wrappings, so as to preserve it from the action of the atmosphere, being designed to enable the manufacturer of these caustic alkalies to put them up in original packages of uniform sizes and weight, of such convenient size that when a package is open the whole may be used at once. In one of the modes described the caustic alkali is poured in a molten state into sheet tin boxes cemented at their edges, and while the molten alkali is hot the lid is closely fastened down, so as to exclude the atmosphere.

The late Judge McKennan, in deciding the case in the United States Circuit Court of this district, said, *inter alia:*

" A graver question is that which brings in question the patentability of the alleged invention. A patentable subject must be not only new and useful, but it must involve some exercise of the inventive faculty, and it must not be merely the application of an old thing to a new use. It is undoubtedly true that small metal cans and infusible cement were in use before Thompson's invention, and that caustic alkalies were preserved from deliquescence by inclosure in air-tight packages of glass, iron and wood; but still the fact remained that caustic soda was unavailable for general use, and especially for the domestic manufacture of soap. By Thompson's method it was invested with commercial properties and practical adaptabilities which did not pertain to it before. . . . The patentability of an alleged invention is, in many cases, most satisfactorily shown by its *utility*. In Webster, on 'Subject Matter,' 30, it is said: 'The utility, then, of the change, as ascertained by the consequences, is the real practical test of the sufficiency of an invention; and since one cannot exist without the other the existence of one may be presumed in proof of the existence of the other.' . . . Judged by the standard of utility, then, a sufficiency of invention to support this patent is to be presumed."

It will be clearly seen from this brief consideration of the question, What is patentable invention? that it is by no means easy of definition, and the difficulty of establishing a positive rule applicable to all cases will be fully appreciated.

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from p. 366.*]

We will next consider the subject of drawing. That this is an absolute necessity to the engineer I think no one will deny.

Drawing, to a great extent, is his language. It is the method by which he expresses a large class of his ideas. Go into any extensive shop or manufactory where they make a business of manufacturing machinery or of building structures, and you will find that all operations are controlled through the draughting room. Drawings must be made of every piece that is to be manufactured, and of every machine or structure that is to be erected, and either the drawings themselves, or tracings made from them, or blue prints taken from the tracings, are sent into the shop, and these form the instructions of the workman how to make the pieces. In many establishments, it is the chief draughtsman who has charge of designing the machines and structures, so that when this is the case the chief draughtsman becomes practically the engineer of the establishment.

Moreover, neatness and accuracy must prevail in the drawings, so that they can be easily understood, for a mistake made by the draughtsman on a drawing, or a misunderstanding of the drawing by the workman, if not discovered in time, may result in a large pecuniary loss to the manufacturer.

Freehand drawing and lettering are both very important matters, *i. e.*, freehand drawing is needed to such an extent as will enable the young man to sketch easily and readily any part of a machine or structure, and to do this work with sufficient speed and clearness to be able to complete it while he has access to the machine, so that he can subsequently make a complete set of working drawings from his sketches, a thing which is often necessary when a draughtsman is sent outside for information. Neat lettering and dimensioning add very materially to the clearness of a drawing, and hence render it less likely to be misunderstood; and this is especially necessary since the workman should always be instructed to make use of the figured dimensions, and should never be allowed to scale a drawing.

Graphical methods are sometimes employed for the making of calculations necessary in the designs of machines or structures, and when these are used, of course, great accuracy is an absolute necessity in making the drawing. Seeing now that drawing plays so large a part in any engineering work, let us consider how it should be taught, and how the course should be laid out.

We may say that there are two objects to be accomplished, the first being the execution, and the second the power to express ideas by means of drawing, and to read the ideas of others, which have been expressed by the same means; in other words, to be able to produce, from the piece itself, the necessary working drawings, and *vice versa*, when, having the working drawings, to be able to understand how the machine is made in all its details.

A certain amount of time will have to be employed at the outset to teach the use of instruments and to enable the student to perform the actual work of drawing, observing, of course, accuracy and neatness. But as soon as this necessary preliminary training in execution is accomplished, so that the pupil begins to do his work with a fair degree of accuracy and neatness, then the attempt should be made at once to have him acquire the language, so that he can readily translate ideas into drawing, and *vice versa*. Now, the mathematical basis of drawing is descriptive geometry, hence the student should be set at once to study descriptive geometry, being made to work out and demonstrate the propositions on the blackboard, as in any other mathematical class-room exercise; and he should be made to take a broad view of the subject so that he will understand the drawing, whatever be the angle, whether first, second, third or fourth, in which it is made, or if it is partly in one and partly in another. I do not believe in the method that confines him to the first angle for a long time, until he gets so used to that particular angle that the moment a figure is placed in any other it looks difficult to him. Indeed, in practice all angles are used, but if one is employed more than others it is the third and not the first. But the student has only obtained a firm grasp on the subject when he is equally at home and familiar with the figure in whatever angle it is placed.

Then, parallel with the class-room work, where he is taught the theory, or, in other words, descriptive geometry, he should be obliged to make correct and accurate drawings, giving the constructions for a certain number of the problems of descriptive geometry. The only difficulty in the matter will be found at the very beginning in making the student exercise his imagination sufficiently to grasp the central idea of projections in any of the angles. In this he must be thoroughly drilled; the rest is then easy. I might add that here also the teacher should have in view in laying out the propositions to be studied by the class, the needs of an engineering course; and while they should be comprehensive, and cover all the main principles, they should be chosen from the point of view of engineering and not from a desire to keep as nearly as may be to the course which was originally given by Monge, the father of descriptive geometry.

Now, when our student is familiar with descriptive geometry, and has made reasonable progress in execution, and understands how to express ideas on paper, at least as far as descriptive geometry goes, the next step to take is to cause him to make working drawings from measurements made by himself of pieces of machinery, or of structures; thus teaching him how to determine what views of a piece it is necessary to make, how to arrange the drawings on paper and how to dimension them.

However, at the outset, we are confronted with the fact that every different works has its own system of making drawings, differing from one another in some minor details, usually in the manner of putting on dimensions and sometimes in the manner of putting on shade lines, or some other minor things; *i. e.*, things about which it is of minor importance which system is followed, but where it is of the very greatest importance that some one consistent system should be employed.

Now, some one good system ought to be chosen, and the student should be made to adhere to it. Also such, conventions and rules as are universally adopted should be taught him, such for example, as that the diameter and not the radius of a piece that is to be made in a shop should always be designated; that the over-all dimensions of pieces should always be given, etc.

After the student has done a reasonable amount of this kind of drawing, which might be called drawing from models, he should next be required to make the detail drawings for the separate pieces of some machine, and having done this, should make the assembly drawings from these detail drawings, thus learning how the separate pieces are to be put together to form the complete machine, to detect errors in the detail drawings, and how all this is to be represented on paper. Such a course of instruction is necessary in order to give the student the training needed to enable him to carry out the reverse process, which is the course he will most frequently have to follow in the draughting-room of the works.

For drawing, pure and simple, such a course as that outlined will probably give a reasonable skill in executing and in making and reading drawings. Of course, however, there ought to be, if possible for all, and without fail for those who are aiming towards topographical work, a reasonable amount of drill in topographical drawing; then for all there should be, as I have said, instruction in freehand drawing, and also in plain lettering.

As to the drawing done in connection with the other work of the students, which would naturally form a very considerable portion of their total drawing, I shall not speak here, for it belongs in connection with the other work; the students are supposed to have acquired the language of drawing and to use it whenever needed.

Perhaps I ought to mention, also, that all engineering students should be taught to make blue prints, an easy matter as far as teaching it to the student goes, but one of the greatest importance in practice.

It is almost impossible to understand to-day how we ever could get along in our large shops and manufactories of machinery and of structures without the use of blue prints. In former times drawings had to be made, of course, of all the parts of the machine, and then tracings of each part to send to the shop for the use of the workmen. These tracings were often spoiled in the shop, and more had to be made, involving a large amount of labor; also, if the purchaser of the machine wished a tracing, one had to be made for him. As things are now, the original drawings are generally made in pencil, these being seldom inked. Then one tracing is made, and from this are taken as many blue prints as are desired. If one is lost or spoiled, it can be replaced with very slight labor and at small expense.

Next comes mechanism, which may be said to be the most elementary of the subjects that are commonly considered to constitute the strictly professional work of a mechanical engineer. It deals with the combination of the motions by means of which each machine is enabled to accomplish its own special functions when the power has been furnished to it.

Were I to undertake to give a list of cases where the invention of certain special mechanisms have revolutionized certain industries, or have advanced enormously the industrial progress of the world, or caused a great saving of labor, and brought about incalculable benefits for mankind, my task would be almost endless.

The invention of different combinations, and, hence, the introduction of machinery of different kinds, by means of which the industrial progress of the world has been rendered possible, began in the very earliest ages, long before the advent of steam, and even back in the days when the only sources of power were the work of men and of animals. Indeed, had it not been for machinery the industrial progress, and, hence, the civilization of the world would have been impossibilities. There would have been no commerce, and no occasion for roads or means of communication, for the world would have remained in a savage state. Consider what was the condition of the textile industries even just before the time when Hargreaves invented the spinning jenny, and Arkwright the spinning frame, and Crompton the mule, compared with their condition to-day, and you have an example, in one department, of what machinery has rendered possible, and of how incalculable are the benefits that it has conferred on mankind. Then they had only the hand-spinning wheel, and the amount of work that could be accomplished was very small. The inventions of Hargreaves, of Arkwright and of Crompton were merely combinations of mechanism, and, although they still used manual labor or horse-power, the amount of yarn that one person could produce was many times what could be accomplished by the same person with the hand-wheel. To-day we should look upon these machines of Hargreaves, Arkwright and Crompton as exceedingly crude, and instead there has been developed all the wonderful variety of marvellous machinery that hums in the different textile manufactories of the world, furnishing us with all the delicate and rich fabrics with which we adorn our persons and our houses at the present day, our cotton goods, our woollens and worsteds, our silks and satins and laces, our carpets and our tapestries, etc.

Coming down to a later date, consider the enormous saving of labor, and the enormous increase in the product of the labor of one individual, by the introduction of the sewing machine, even leaving out of account the fact of driving it by water or steam power. Consider how very general is its use, that one can hardly enter a private house that is without one, to say nothing of the enormous number used in manufactories of clothing and of other articles which are made by sewing.

Furthermore, it has found its way, with some modifications into the manufacture of shoes; and in this industry we find a great number of special machines in use which are simply combinations of mechanism designed to accomplish certain special results.

Then consider the tools used in our machine shops, and places where machinery is manufactured; the lathes, the planers, the drills, the shapers, the milling and the grinding machines, the gear cutters, and the host of special machines in constant use all over the world.

Consider the bolt and nut machines, the machines for making barbed wire, the nail machines, the screw machines, and a host of others too numerous to mention. To call them labor-saving devices is a misnomer, for they rather render possible the work of the world, such as it is at the present day, which would be an utter impossibility without their aid.

The methods of combining the different parts of a machine, so as to obtain the desired motions, have been reduced to a system, and this system constitutes the study of mechanism.

It aims to make the student familiar with the methods by which such results are to be accomplished, and to teach him the principles governing them, so that he may undertake intelligently the devising of new arrangements, and may avoid making or proposing absurd, impossible or unadvisable combinations. It depends mainly on pure mathematics and involves a knowledge of drawing. The mathematics principally needed are algebra, geometry, trigonometry and descriptive geometry, while it is very useful and will often save work and enable one to reach results more easily to have a knowledge of analytical geometry and calculus.

Drawing is, of course, indispensable also. We might well say that mechanism is a mathematical subject, and teaching it requires the use of the class-room and the drawing-room. To a certain extent it is desirable and almost necessary to use models also, but care should be taken that the student fully understands a drawing; for if, in order to work out a combination, he finds it necessary to build or look at a model before he can predict with certainty what it will accomplish, he has not properly learned his mechanism. In order to have a knowledge of the subject that is sufficient to enable him to make real use of it in practice, he must be able to put his ideas into shape in a drawing readily and quickly, and to predict the mode of action from this drawing and such mathematical calculations as he may make. If, on the other hand, a drawing is presented to him, he should understand how the machinery represented will behave, and what can be expected of it. Moreover, he should be able to do this with mechanism of very considerable complexity, for he will often meet with such machinery in the course of his practice.

Now, after he has had his systematic study of mechanism, it seems to me that it is of great importance that he should make a study of the usual machine tools that are in general use to-day, such as lathes, planers, milling machines, etc., studying first the characteristics of the usual mechanisms they contain, noticing the reasons for choosing some and not others; as, for instance, the questions of stiffness, of wear of the surfaces, of stability, etc. Of course, he should have an opportunity for studying some forms of these by personally inspecting them in the shops attached to the institution, but these are necessarily limited in size, and there is also an enormous variety of other combinations in common use for different purposes. This work can best be accomplished by the teacher, probably, if he puts in the hands of the students a large and systematically selected collection of cuts of the machines in general use made by some of the best makers. The teacher, of course, must be familiar with these machines, and he must be able to explain to the class their general as well as special features, and see that the student becomes familiar with them. A little instruction of this sort will be of great service to the student in many ways, both in his course and in his subsequent work in the practice of his profession.

Another thing that, in my opinion, is very desirable to do by way of making the student's study of mechanism serviceable to him, I will now explain.

In the study of machine tools just referred to, the student gains a familiarity with the characteristics of those kinds of machinery which he will meet with at every turn; but, as a rule, the ordinary machine tools cannot be said to involve a very large amount of complicated mechanism; hence, something should be done by way of making him thoroughly familiar with certain classes of machines that, in order to accomplish their objects require a large amount of very complicated mechanism. Hence, he should be taught the construction of some such machines in all their details, and then, if possible, he should find in the laboratory examples of some of these machines, and be made to understand them in detail—as it were, to dissect them, to see for himself that they do accomplish what is claimed for them, and to verify, by his own computations from the dimensions of the parts, whether the actual motions are such as agree with his calculations; and if not, to find out why they are not, or, in other words, wherein he made his mistakes in calculation. Now, it matters comparatively little what kinds of machines these are, provided only that some of them, at least, involve a very considerable complication. In the case of our own classes, we have a lot of textile machinery, the most complicated of which is a spinning mule; and the students are required to become thoroughly familiar with the action of all the parts of these machines. For example, in the case of the mule, they must understand thoroughly what is the mechanism for carrying out and returning the carriage, and how this is caused to vary its speed at different times; what is the mechanism that does the twisting; what the winding; how the roving is drawn out in the beginning, etc. By having such a machine in the laboratory the student can be made to study and understand it; whereas, in a mill the mules could not be stopped and run at his convenience and for his benefit. Moreover, after the student has had a good course in mechanism, and has then had to render himself familiar with all the parts of a machine as complicated as a mule, he is better prepared to grasp and understand complicated mechanism of any kind; as, for instance, a barbed wire machine, a bolt and nut machine, an automatic screw machine, etc.

Then, again, there is a special class of problems in mechanism, which concern machines that generate power, as the mechanism of the steam engine; but the one portion of the mechanism of the steam engine that requires special attention is the valve gear. Hence, the student should have such thorough instruction in valve gears and link motions as shall drill him in the mathematical principles for working out valve gears in all their details, and should also be taught the different ways of designing and making those in use to-day, the ways of constructing them and their adjustments, all this being really a part of the mechanism course.

Now, although I have already met and answered a question that might arise in the minds of some, it will, perhaps, be worth while at this point to raise and answer it again. It is this: Is it as important for the young man who expects to devote himself to what is commonly called civil engineering to be thoroughly drilled in mechanism as it is for the mechanical engineer? and I answer very decidedly, yes. The civil engineer who is to build bridges or engage in some of the kinds of engineering which I enumerated under my list of so-called public works, cannot carry on any work of any magnitude without having to use a good deal of machinery, and is liable to have to use special machinery; and the more important the work on which he is engaged the greater the use he has for machinery of all kinds; and if the development that has taken place up to the present time is any sign of what is to take place in the future, he will be more and more intimately concerned with the use of machinery, which he will need to direct, to set up, and perhaps even to design.

Another matter to which it may be well to refer is that a thorough knowledge of the principles of mechanism will tend to guard the prospective engineer against the danger of inventing absurd and impossible combinations of mechanism and impracticable machines, or to expect to accomplish by means of mechanism only results that cannot be accomplished by it alone.

Indeed, were I to attempt to give you a list of all the worthless and absurd inventions of the world, I should probably find that the greatest part of them consisted of some form of mechanism. The very fact that the invention of certain machines, *i. e.*, of the mechanism of those machines, has had such a powerful influence on the welfare of mankind is, of itself, an invitation to a great many people who are ignorant of scientific principles, and also of the requirements of machinery, to try their hands at inventing, and the patent offices of the world contain an enormous number of such worthless contrivances.

The next course of which I shall speak is one which vitally concerns the engineer at every turn, and, therefore, one in which it is absolutely necessary that he should be very thoroughly drilled. The course to which I refer is theoretical and applied mechanics. This term has been used in different senses at different times, and in different places, but the sense in which I shall use it is that which is now most generally accepted; *i. e.*, it includes a general and mathematical discussion of the action of forces upon bodies at rest or in motion, and also a full treatment of the strength and elasticity of the materials used in construction, both from a mathematical and also from an experimental point of view. To speak more in detail, it includes a treatment of such subjects as the following, viz.: composition and resolution of forces, conditions of equilibrium, determination of the centers of gravity, of lines, areas and of solid bodies; the general laws of dynamics, as a treatment of uniform and varying motion; the pendulum, determination of moments of inertia, and of centers of percussion, etc.; the laws of friction; determination of the work used up in friction, both by mathematical calculation and by actual experiment. Then come the determinations of the stresses in the different members of trusses of all sorts; and then a study of the mathematical discussion of the theories of the strength and elasticity of materials, *i. e.*, study of the distribution of the stresses acting in tension rods, struts or compression pieces, beams or other pieces bearing a transverse load; also in all sorts of pieces that are subjected to shearing, including, of course, riveted joints, shafting and beams, as well as in other pieces; the distribution of the stresses acting in a hook, or in any tension or compression piece that has to bear an eccentric load; the determination of the greatest intensity of the stress, or, in other words, of the stress acting on the most strained fibre in each case; also the determination of the strains (elongations in the case of tension, and shortenings in the case of compression pieces) that occur in all the different parts of the piece; the modes of determining the deflections of beams, the angle of twist of shafts, or the amount of yielding of pieces generally, under load; theories and modes of calculation of the stresses at different parts of continuous girders, *i. e.*, beams which are continuous over more than two points of support; also of the deflections of, and the shearing stresses of, such beams; determinations of the stability of, and of the stresses acting in, arches which bear a load, whether they are of stone or iron; theory of the stability of domes, and then a study of the theory of elasticity.

Turning to the experimental side, the student should be familiarized with what experiments have been made upon and what results they have shown as regards the strength and the stiffness of such pieces as are used in construction to bear a load. Moreover, the account of these experiments should be brought up to date, and special emphasis laid on the results of those where the conditions of practice, as to size, manner of loading and treatment generally, have been exactly, or at least approximately, copied. The student should be made to study carefully the results that have been obtained in these experiments, to collate and compare, and to draw from them such conclusions as are warranted, to see how far and in what ways they may modify the ordinary mathematical calculations and the ordinary ideas in regard to the action of such pieces in bearing loads. To study the effects of the repetition of stresses to which pieces are very frequently subjected in practice; in short, to put himself as nearly as possible in such a condition that he knows what is the extent of our knowledge of the facts as shown by experiment in regard to the behavior of the materials of construction, wood, iron, steel, stone, cement, concrete, etc., when subjected to such loads as they have to bear in practice.

It would seem almost unnecessary to say that such subjects as the above are of the most vital importance to the engineer, and yet, absurd as it may seem, there have been those, and there are still occasionally some, who consider such information as of no consequence. These are the men who believe in doing their work by rule of thumb; and they would proportion the parts of any machinery or structure which they might have to build by one of two methods, either of which they would call practical, for the reason only that it lacks the element of scientific knowledge. The first method is, if the thing to be designed is similar to something that they are familiar with, to copy that—whether it is right or wrong, whether it is far stronger than need be, or on the verge of collapse—simply because they are following a precedent; if it is to be of the same sort as something that has gone before, but is to be of greater or less capacity, they are very liable to determine the sizes of the new one from those of the old one by the rule of three; or, if the new machine or structure is wholly unlike anything they have seen before, or if, though like something they have seen before, they decide not to copy the old, they determine what dimensions to give it by guessing, and call their guesses practical experience, notwithstanding the fact that they are often very poor guesses.

The second, and more usual method which such men are liable to follow, is to determine the dimensions of the pieces by means of formulæ found in some handbook, and they assume that because a formula is found in a handbook, or rather in the handbook which they have adopted as authority, therefore, it must be right, trusting blindly to the correctness of the formula and constants given in these handbooks, although they have no knowledge of the assumptions made in the deduction of the formulæ, nor of the experimental basis upon which the determination of the constants rests.

It is needless to say that either of these methods is liable to, and often does, result in disaster, and accident after accident has resulted from, and lives have been lost in consequence of, the use of each of such methods as these.

The consequences of structural weakness in any member of a structure or machine are:

(1) Lack of the necessary stiffness, and hence, in the case of a machine, the turning out of poor work; or, in the case of a structure, oscillations which render it unsuitable for the performance of fine and accurate work of any kind.

(2) Breakage of the structure or machine.

(3) Injury to surrounding objects, personal injury, and perhaps loss of life.

Hence it is very important to provide the requisite strength and stiffness in all the members of the structure or machine. Increase of the amount of material does not necessarily mean increase of strength.

The first step towards determining the proper dimensions for any piece, in order to secure the requisite strength and stiffness, is to know the forces acting upon it, and how they act.

Then we need to determine the stresses to which the piece is subjected, in consequence of the action of these forces, and also the strains, *i. e.*, the elongations, compressions, deflections or deformations due to these stresses.

Next, whether the forces are quiescent, or whether they are oft-repeated, and what are the conditions of the repetitions.

Then we are ready to determine what dimensions we must adopt in order that the greatest stresses at any point shall not exceed an amount consistent with safety, this amount being determined by experiments made upon the strength of the material, and so that the greatest strain shall not exceed an amount consistent with safety and with the proper stiffness of the machine or structure.

If, for instance, we are to decide upon the proper dimensions to adopt for the different pieces that compose a machine, we need to ascertain, first, what is the greatest force exerted at that end of the train of mechanism where the work is done. It becomes then merely a question of composition and resolution of forces to determine the forces acting on any one piece of the machine. We shall thus find, in general, that some pieces are subjected to direct tension, some to direct compression, some to a transverse load, some to torsion, some to a combination of different stresses, and some to various eccentric loads.

Suppose, now, that we have a structure, for instance a building. We must first ascertain the greatest loads that can come upon any part of the floors, and then determine the stresses produced in the beams, columns, walls, etc., by these loads. But we must also observe that the greatest stresses are not necessarily those produced by the greatest loads, and hence we must determine the loads which produce the greatest stress in each member. Similar remarks apply to a bridge structure.

A few examples will serve as illustrations. Take the case of one of the columns of a building. When the greatest load per square foot covers the entire floor above, the resultant of this load on that floor acts along the center line of the column, and the stress per square inch due to this load is uniformly distributed over the section. When, on the other hand, the floor on one side is fully loaded, and the floor on the other side is not loaded, then the total load is less than in the other case, but its resultant does not act along the center line of the column, but is eccentric. Now, it is plain that the eccentricity of the load introduces a tendency to bend, and, under such conditions the load that will break the column is very much less than it would be when the load resultant is central.

Now, when a column in a building is to be calculated, we should determine what is the greatest stress on one side, due to having as great an eccentricity of load as is possible to be attained in the use of the building, and we should see to it that the dimensions of the column are such that this greatest stress shall not exceed safe limits. Further, if with most of the sizes of columns used in buildings we were to determine the amount of this eccentricity, and also the probable amount of the deflection under any central load that the column would have to carry while in use in the building, we should find that the latter is almost inappreciable compared with the former, and yet it is not at all common for people to-day to compute the stresses due to the eccentric loading, and instead they often use some formula which was devised for central loading, and which was deduced by making certain assumptions in regard to the deflections which experiments on actual full-sized columns do not bear out.

This I call neglecting the important consideration and performing a great deal of computation on a very minor one, by means of a formula that cannot be proved, but which is given in the handbooks. Is it any wonder that columns sometimes fail?

Another illustration is to be found in connection with the calculation of fly-wheels of steam engines. Every once in a while we hear of the bursting of a fly-wheel, the fragments of which have, in consequence of the breakage, been hurled like so many projectiles, in all directions, carrying death and destruction in their paths.

Now, in several cases of wheels which I have examined, the stresses existing in the bolts which unite the separate sections of the rim, and the stresses in the portions of the rim near the joints, were decidedly greater than a due regard for safety would allow, and greater than the designers of the wheels would have allowed had they been designing some other construction, or had they realized their existence in the case of the wheel. The difficulty in these cases, apparently, was that the designer, if he figured at all, disregarded the fact that the bolts were not placed in the line of direction of the resultant of the tension in the rim, but were located on one side of that line, and that therefore they had an eccentric load, and, having neglected to figure the extra stress due to the eccentricity of the load, he did not provide sufficient strength in the wheel to resist it.

Another way in which erroneous results may have been reached is in the misapplication of a rule given in Rankine's books, which applies only when the load is not eccentric.

Another case where disaster occurred in consequence of neglect to consider the effect of an eccentric load (well known to a Boston audience), is afforded by the Bussey Bridge accident, which occurred a few years ago, where, as will be remembered, one of the hangers had a very eccentric pull, while it was only strong enough to bear the load if it had been central. This disaster was the cause, not only of a serious destruction of property, but also of a large loss of life.

Let us turn next from a consideration of the formulæ to the question of the proper constants to use.

If the dimensions proposed for any piece are such that the greatest stresses and the greatest strains in the piece are no greater than the safe allowable stresses and the safe allowable strains, respectively, for that kind of material, then the dimensions chosen are such as are consistent with safety; but if they are larger, the dimensions must be altered so as to bring these greatest stresses and strains within safe limits.

The knowledge of what are safe limits is, of course, an important matter, and can only be determined by experiment.

This principle has, of course, been generally acknowledged for a long time by those who believe, as they should, in calculating the stresses that actually exist, and a great many experiments have been made, and the results of such experiments have been published, and are quoted in books, and, of course, in the handbooks. Now, there are many who accept, as necessarily correct, the constants given in their favorite handbook, without stopping to ascertain under what conditions the experiments were made, and whether or not these conditions are similar to those which exist in the cases they themselves have in hand. The result of such a course is the frequent use of values for allowable stresses which are not suitable to use at all, or which, while suitable in some other case, are not suitable to use in his own case. To make this matter plain, let us use a few illustrations:

In the different handbooks are given various rules and constants from which to determine the breaking loads of wooden columns. Taking the condition of the handbooks a few years ago, the engineer would have found, if he chose to hunt up the records of the experiments upon which most of these constants were based, that their only basis was seven experiments selected out of seventeen, which were made about the year 1840, upon seventeen columns cut out of one good plank of Dantzic oak, which had been cut up and seasoned about one year, the largest piece tested being about two inches square and five feet long; and that since the results obtained from the seventeen did not run very uniformly, ten were thrown aside, and the other seven were used to furnish the constants for the formulæ; and further, that most of the formulæ given in the handbooks took their constants from these experiments, and applied them indiscriminately to wooden columns of all kinds of wood. Moreover, while a few other formulæ were given at that time, they all derived their constants from experiments on small specimens, and made under conditions which rendered them unsuitable to use in actual practice; *i. e.*, the breaking strengths as figured by means of these formulæ and constants were very different from the actual breaking strengths.

Now that experiments on full-size columns of wood have been made, it is found that different kinds of wood differ very considerably in their crushing strengths: that oak, in regard to which the prejudice has almost always existed that it is stronger than yellow pine, is really not as strong as the yellow pine; and that all the figures that are suitable to use for the crushing strength of timber columns of practical size are very decidedly lower than those given by the results obtained by the Dantzic oak experiments already referred to.

When we stop to consider the reasons for these facts, they become evident, viz.: There exist in timber columns of the sizes and proportions used in practice, knots, season cracks, defects and a lack of homogeneity which do not exist in small selected pieces. Hence, since modern experiments made under the conditions of practice have shown us what are really the values suitable to use in computing the breaking strengths of timber columns, it follows that these old constants were entirely inapplicable.

As a matter of fact, a very considerable number of the handbooks and other books now give the new instead of the old constants; but other authors, either through obstinacy or inertia, have not changed their books to keep up with the times in this respect.

In the case of timber beams bearing a transverse load, the number of experiments made on small pieces, about two inches square and five feet long, is very large; and the constants almost universally given in the handbooks until a very recent date were based upon experiments of this kind. The results, however, differed a good deal among themselves, as they were obtained from different sets, but all are decidedly larger than those that have been obtained from modern experiments made on beams of such sizes as are used in practice, and for the same reasons that were explained in the case of timber columns.

The condition of things to-day, therefore, is that some of the handbooks still adhere to the old constants, differing, however, among themselves, and that others have brought their books up to the times in this regard, and give the new constants derived from the modern experiments, although not all the handbooks that give reliable constants for columns do the same for beams, nor do all those which give reliable constants for beams do the same for columns.

Until within the past five or six years, the building laws of the city of Boston prescribed that in the case of timber columns and timber beams the safe load to apply should be considered as one-third of the breaking load, the breaking load being calculated from such constants as are given by any good authority. The law did not prescribe any method of determining what is good authority, and hence left it to be tacitly assumed that any of the handbooks, or books of that character, which were used by reputable engineers or architects, might be considered as good authority. In accordance with these directions, what a man would call the breaking load of a given yellow pine beam would depend upon which handbook he happened to get his constants from.

Let us suppose that he took as his authority Hatfield's experiments on yellow pine beams, about 2 inches square and 5 feet long, and used the average of his results. In this case, he would find for extreme fibre stress, when the beam was just on the point of breaking, 15,000 pounds per square inch. Applying to this the factor of safety 3, as required by law, he would find the safe load by allowing an extreme fibre stress of 5,000 pounds per square inch, whereas modern experiment shows that, for beams of practical size, it is liable to be on the verge of breaking when the extreme fibre stress reaches 5,000 pounds per square inch.

Indeed, it is only within the last twenty years that much activity has been displayed in testing the strength of pieces of practical size, and that a flood of light has been thrown on the question as to what are not reliable constants to use in practice. In the case of most of the constants given for iron and steel, the greater part of them have generally been nearer to the truth than in the case of timber, but there has been a very considerable lack of accurate information on the subject.

[*To be concluded.*]

BOOK NOTICES.

Transition Curves.—A field-book for engineers, containing rules and tables for laying out transition curves. By Walter G. Fox, C.E., New York: D. Van Nostrand Company. 1893. Van Nostrand's Science Series, No. 110. 80 pages. 50 cents.

The author here submits six tables, each representing a different transition curve. These curves differ from one another in the rate at which the curvature increases with the number of chords laid off. The tables give the co-ordinates for locating the points at the ends of the chords, as well as the deflection angles, in order that the curve may be run by offsets, if desired. The usual tables of radii and apex distances are also given. T.

Encyclopédie scientifique des Aide-Mémoire. Dirigée par M. Léauté, Membre de l'Institut. Librarie Gauthier-Villars et fils. Quai des Grand-Augustins, 55. Price, per volume, 2·50 francs, unbound; 3 francs, bound.

Since our last notice of this capital technological series, the following additional volumes have appeared:

Hennebert. Lieutenant-Colonel du Génie, ancien Élève de l'École Polytechnique. *Fortification.*

Sorel, E. Ancien ingenieur des manufactures de l'État. *La rectification de l'alcool.*

Alheilig. Ingénieur de la Marine. *Résistance et construction des pièces des Machines.*

Billy, E. de. Ingénieur au Corps des Mines. *Fabrication de la Fonte.*

Minel, P. Ingénieur des Constructions navales. *Électricité appliquée à la marine.*

Minel, P. Ingénieur des Constructions navales. *Régularisation des moteurs des machines électriques.*

Dwelshauvers-Dery. Ingénieur, Professeur à l'Université de Liège. *Étude expérimentale dynamique de la machine à vapeur.*

Marchena, R. de. Ingénieur des Arts et Manufactures. *Machines frigorifiques à gaz liquéfiables.*

Marchena, R. de. Ingénieur des Arts et Manufactures. *Machines frigorifiques à air.*

W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 21, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 21, 1894.

MR. H. R. HEYL, in the chair.

Present, seventy-six members and four visitors.

Additions to membership since last report, twelve.

Mr. John C. Trautwine, Jr., described, with the aid of lantern projections, the subway which is about to be constructed jointly by the City of Philadelphia and the Philadelphia and Reading Railroad Company, and which has for its principal object the abolition of the numerous grade crossings of the Reading Company's tracks which now exist on Pennsylvania Avenue, between Broad Street and the entrance to the Park at Fairmount Avenue.

The dominant feature of the plan is the depression of the railway below the street level, from a point east of Broad Street westward to Twenty-sixth Street, whence the tracks will rise to the present surface level at Thirtieth Street.

From Broad Street westward to Twenty-first and Hamilton Streets, the railroad will occupy an open subway, over which the several north and south streets will be carried upon iron bridges, while from Twenty-first Street northwestward to Twenty-sixth Street it will be in a tunnel, which is to be surmounted by a boulevard.

The operations now under way are confined to the construction of the two elaborate systems of low-level sewers necessitated by the plan. These empty into the Schuylkill River at the foot of Powelton Avenue, whence they extend, respectively, eastward along Callowhill Street to Thirteenth Street, and northwestward along Pennsylvania Avenue to Thirtieth Street. Their maximum depths below the street surface are, respectively, about forty and fifty feet.

Mr. J. L. Gill, Jr., gave a description of the remarkable explosion of a battery of steam boilers, which occurred in October last at a colliery near Shamokin, Pa. The speaker illustrated his remarks by the exhibition of a number of projections of photographs taken on the scene a few days after the disaster had occurred. The subject was freely discussed.

Mr. W. N. Jennings exhibited a series of pictures of the launch of the ocean liner, *St. Louis*, from the Cramps' shipyard, which took place on November 5th.

The Secretary's report included a reference to the several projects for bridging the Hudson River at New York. A view, showing a plan of cantilever bridge of 2,100 feet span, and a suspension structure of 3,100 feet span, was exhibited, and estimates of the cost and other details were stated.

Adjourned. WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR JULY, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, July 31, 1894.

GENERAL REVIEW.

The average temperature for July, 73°·8, is 3°·2 above the average [70° 6] for the last six years, and is 1°·8 above the highest average during that time.

Extremely hot weather prevailed on the 1st, 19th, 20th, 28th and 29th, during which time the following high temperatures were recorded at the stations named: Huntingdon, 103°; Lock Haven, 102°; Logania, 102°; Hollidaysburg, 101°; Hamburg, 101°; Blooming Grove, 101°; Carlisle, 100°; Wilkes-Barre, 100°; and Lewisburg, 100°.

The coolest weather occurred on the 6th, 7th, 8th, 9th and 10th, and the lowest temperatures recorded were: Lock Haven, 31°; Saegerstown, 35°; Kane, 38°; Smethport, 38°; Somerset, 38°; Huntingdon, 39°, and Greenville, 39°.

The extremely warm and dry weather, with high percentage of sunshine, was favorable for maturing wheat, harvesting and haying, but these conditions continuing throughout the entire month, produced a general drought which was injurious to growing crops.

From January 1, 1894, to July 31, 1894, the excess in temperature at Philadelphia was 464°; at Erie, 519°, and at Pittsburgh, 416°.

For the same period the deficiency in precipitation at Philadelphia was 2·28; Erie, 3·74, and Pittsburgh, 6·00.

TEMPERATURE.

	Mean Temperature.	Mean Precipitation, Inches.
July, 1888,	69°·4	3·45
1889,	71°·2	6·80
1890,	70°·8	3·52
1891,	67°·9	6·32
1892,	72°·0	3·93
1893,	72°·0	3·15
1894,	73°·8	2·32

The means of the daily maximum and minimum temperatures, 86°·0 and 61°·6, respectively, give a monthly mean of 73°·8, which is 1°·8 above the corresponding month of 1893.

The average daily range was 24°·4.

Highest monthly mean, 79°·2 at Swarthmore.

Lowest monthly mean, 67°·5 at Wellsboro.

Highest temperature recorded during the month, 103° on the 19th at Huntingdon.

Lowest temperature, 31° on the 9th at Lock Haven.

Greatest local monthly range, 72° at Lock Haven.

Least local monthly range, 36° at Drifton.

Greatest daily range, 54° at Lock Haven.

PRECIPITATION.

The average precipitation for the State, for the month, 2·32 inches, is 2·21 inches less than the average [4·53] for the last six years.

While showers were fairly numerous, they were light and badly distributed, and only a few localities received enough to exempt them from the general drought.

The largest monthly totals were Pottstown, 5·96; Coatesville, 4·61; Lebanon, 4·42; Grampian, 4·06; Kennett Square, 4·04; and Stoyestown, 3·91.

The least were Easton, 0·53; *Philadelphia* [Centennial Avenue], 0·65; Beaver Dam, 0·65; Honesdale, 0·71; Wilkes-Barre, 0·74, and *Philadelphia* [Weather Bureau], 0·75.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 7; clear days, 15; fair days, 11; cloudy days, 5.

BAROMETER.

The mean pressure for the month, 30·01, is about ·05 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·22 at Erie on the 26th, and Philadelphia on the 27th, and the lowest 29·73 at Philadelphia on the 6th.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Hollidaysburg, 20th, 23d; Quakertown, 1st, 6th, 21st, 24th, 26th, 31st; Cassandria, 1st, 2d, 6th, 20th, 28th, 29th, 31st; Johnstown, 2d, 14th, 28th, 29th; Emporium, 1st, 20th, 29th; Mauch Chunk, 26th, 29th, 30th; State College, 20th, 28th; West Chester, 6th, 16th, 21st, 28th; Coatesville, 6th, 14th, 16th, 21st, 24th, 31st; Kennett Square, 6th, 16th, 21st; Phœnixville, 6th, 24th, 29th; Grampian, 2d, 20th; Lock Haven, 26th, 28th, 29th; Bloomsburg, 13th, 23d, 26th; Saegerstown, 20th; Harrisburg, 6th, 14th, 24th; Uniontown, 2d, 4th, 6th, 14th, 20th, 21st, 29th, 30th; Lebanon, 1st, 6th, 17th, 24th, 29th; Coopersburg, 1st, 6th, 16th, 24th, 26th, 29th, 31st; Kane, 13th, 15th, 20th, 23d, 29th; Pottstown, 21st, 31st; Logania, 24th, 29th; *Philadelphia* [Weather Bureau], 16th, 17th, 21st; [Centennial Avenue], 6th, 16th, 17th, 21st, 31st; Blooming Grove, 6th, 15th, 16th, 18th, 28th, 29th; Shingle House, 20th, 24th, 29th; Somerset, 14th, 20th, 21st; Lewisburg, 6th, 20th, 24th, 28th, 29th; Salem Corners, 1st, 2d, 6th, 15th, 16th, 17th, 18th, 19th, 20th, 22d, 26th, 27th, 28th, 29th, 30th; South Eaton, 1st, 6th, 20th, 24th, 27th, 29th; York, 6th, 14th, 16th, 26th, 29th.

Hail.—Cassandria, 31st; Lock Haven, 23d, 26th; Somerset, 20th; York, 16th.

Frost.—Cassandria, 9th; Lock Haven, 9th; Saegerstown, 9th; Kane, 9th; Somerset, 9th, 10th.

Aurora.—Edinboro, 7th.

Solar Halo.—*Philadelphia* [Weather Bureau], 15th; [Centennial Avenue], 3d, 30th; Wellsboro, 12th, 27th.

Lunar Halo.—Cassandria, 11th; *Philadelphia* [Centennial Avenue], 15th.

SEPTEMBER WEATHER.

From United States Weather Bureau Records.

The following data, compiled from the records of observations taken during the length of time given at each station, show the average and extreme conditions during that time, and also the range within which weather variations may be expected to keep in any future September.

	Philadelphia. (23 years.)	Pittsburgh. (23 years.)	Erie. (21 years.)
Mean or normal, ...	67°	65°	64°
Warmest September, ... Average, ...	1881 75°	1881 75°	1881 72°
Coldest September, ... Average, ...	1871 63°	1871 59°	18 8 59°
Highest temperature recorded, . . . Date, ...	102° 7th, 1881	102° 6th, 1881	92° 5th and 6th, 1881, 13th, 1887
Lowest temperature recorded, . . . Date, ...	40° 30th, 1888	35° 25th, 1879	37° 9th, 1888
Average date of first "killing" frost (autumn), ...	Oct. 28th	Oct. 21st	Oct. 15th
Average precipitation (inches), . . .	3·32	2·75	3·88
Average number of days with ·01 inch or more, ...	10	10	12
Greatest monthly precipitation, . . Date, ...	12·09 1882	7·35 1876	8·42 1876
Least monthly precipitation, ... Date, ...	0·20 1884	0·76 1881	1·13 1893
Greatest amount in 24 hours, ... Date, ...	4·81 22d, 1882	3·38 17th, 1876	3·40 2 st and 22d, 1882
Average number clear days, ... Partly cloudy, . . Cloudy, ...	11 10 9	9 13 8	10 12 8
Prevailing direction of wind, ...	SW	NW	S
Highest velocity, miles per hour, . Date, ...	54 11th, 1889	38 3d, 1891, 25th, 1892	43 16th, 18:8

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR JULY, 1894.

COUNTY.	STATION.	Elevation above Sea Level (feet).	TEMPERATURE.										PRECIPITATION.				NUMBER OF DAYS.			Wind. Prevailing Direction.	OBSERVERS
			Mean.	MAXIMUM. Highest.	MAXIMUM. Date.	MINIMUM. Lowest.	MINIMUM. Date.	Mean of Maximum.	Mean of Minimum.	DAILY RANGE. Mean.	DAILY RANGE. Greatest.	Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.		
Allegheny,	Pittsburgh,	820	76·0	97	19	49	9	86·7	65·8	20·9	28	1·16	...	...	12	10	18	3	NW	O. D. Stewart, W. B
Berks,	Hamburg.	380	76·0	101	1	49	8	89·3	62·6	26·7	39	3·02	...	...	8	6	22	3	W	William Shipe.
Berks,	Reading,[2]	280	76·2	...	...	...	...	...	...	...	...	2·39	...	...	8	...	...	...	...	Franklin Yager.
Blair,	Altoona,	1,181	77·4	97	2	51	9	88·2	66·7	21·5	27	1·01	...	...	5	...	...	...	...	Dr. C. B. Dudley
Blair,	Hollidaysburg (17 days),	947	74·6	101	19	50	17	90·3	58·8	31·5	45	2·03	...	...	7	5	8	4	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	71·2	96	20	48	8, 10	81·5	61·0	20·5	27	2·98	...	...	15	7	17	7	SW	G. W. T. Warburton
Bucks,	Forks of Neshaminy,[1]	304	75·2	...	...	...	...	...	...	...	...	5·92	...	...	8	14	13	4	W	J. C. Hilsman.
Bucks,	Quakertown,	536	73·8	98	28	45	10	86·6	61·1	25·5	36	1·97	...	...	6	8	20	3	SW	J. L. Heacock.
Cambria,	Cassandria	2,100	74·8	93	19	51	9	81·1	68·4	12·7	22	1·69	...	...	8	5	22	4	SW	A. H. Boyle.
Cambria,	Johnstown,	1,184	73·5	99	19	44	8	87·9	59·1	28·8	40	1·87	...	...	8	5	19	7	...	E. C. Lorentz.
Cameron,	Emporium,	1,050	70·5	94	19	44	10	83·8	57·2	26·6	37	2·09	...	...	7	7	21	3	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	73·3	99	20	44	10	87·4	59·2	28·2	41	2·12	...	...	10	19	6	6	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	72·0	96	19	45	9	83·6	60·4	23·2	33	2·10	...	...	9	14	12	5	W	Prof. Wm. Frear.
Chester,	West Chester,	455	75·6	94	28	53	10	84·5	66·8	17·7	26	3·86	...	...	9	19	4	8	S	J. C. Green, D.D.S.
Chester,	Coatesville,	380	75·2	97	28	50	10	87·0	63·5	23·5	34	4·61	...	...	8	18	10	3	S	W. T. Gordon.
Chester	Kennett Square,	275	74·9	96	13	48	10	85·8	64·0	21·8	33	4·04	...	...	8	20	6	5	SW	B. P. Kirk.
Chester,	Phœnixville,	190	75·1	95	28, 29	49	10	85·3	64·9	20·4	29	3·06	...	...	8	18	8	5	SW	Knowles Croskey.
Chester,	Westtown,	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	John D. Carter.
Clearfield,	Grampian,	1,450	72·2	98	19	48	9, 10	84·1	60·2	23·9	32	4·06	...	...	9	10	17	4	SW	Nathan Moore.
Clinton,	Lock Haven,	560	69·4	102	18	31	9	91·6	47·1	44·5	54	2·86	...	...	6	13	12	6	W	Prof. J. A. Robb.
Columbia,	Bloomsburg—‡ State Normal School,	500	74·0	98	20	47	10	86·5	61·5	25·0	35	1·97	...	...	4	10	14	7	W	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,	1,200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prf. J. H. Montgomery.
Crawford,	Saegerstown,	1,200	69·6	99	19	35	9, 10	86·2	53·1	33·1	48	1·47	...	...	8	8	15	8	NW	J. G. Apple.
Cumberland,	Carlisle,	480	76·3	100	20, 28	46	10	89·5	63·1	26·4	38	1·96	...	...	6	26	3	2	S	J. E. Pague.
Dauphin,	Harrisburg,	480	76·0	96	20	52	10	86·0	66·0	20·0	28	1·89	...	...	6	17	9	5	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	361	79·2	98	28, 29	53	10	88·8	69·6	19·2	33	2·04	...	...	6	21	6	4	...	Prof. S. J. Cunningham
Erie,	Edinboro,*[1]	190	70·9	92	18	50	6	...	...	...	...	...	...	...	...	...	...	...	W	C. F. Sweet.
Erie,	Erie,	1,400	73·0	91	20	50	9	81·0	65·0	16·0	23	2·26	...	...	7	12	13	6	SW	P. Wood, W. B.
Fayette,	Uniontown,	681	71·8	94	19	44	9	84·2	59·4	24·8	33	2·77	...	...	11	16	12	3	S	Wm. Hunt.
Franklin,	Chambersburg,	1,000	74·6	100	20	44	9	88·4	60·8	27·6	39	0·84	...	...	3	9	17	5	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	73·2	103	19	39	10	88·6	57·8	30·8	46	1·57	...	...	4	15	13	3	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	76·2	97	20, 21	50	10	88·4	64·0	24·4	39	2·21	...	...	3	19	8	4	W	W. E. Bushong.
Lebanon,	Lebanon,	458	74·8	95	1	47	10	87·1	62·5	24·6	35	4·42	...	...	9	16	10	5	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	74·8	94	13	52	10	84·1	65·4	18·7	27	2·65	...	...	9	22	8	1	SW	Dr. M. H. Boye.
Luzerne,	Drifton (25 days),	1,683	77·0	94	20	58	7, 17	86·0	68·0	18·0	28	1·75	...	...	4	11	11	3	N	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	74·4	100	20	46	10	89·1	59·7	29·4	46	0·74	...	...	6	19	8	4	W	A. W. Betterly.
McKean,	Kane,	2,000	68·0	94	19	38	9	80·0	56·0	24·0	35	2·13	...	...	9	19	8	4	SE	C. H. Kemp.
McKean,	Smethport,	1,500	68·0	95	19	38	10	82·5	53·5	29·0	45	2·03	...	...	6	14	10	7	SW	Armstrong & Brownell
Mercer,	Greenville— Thiel College,	1,000	70·2	97	19	39	9	83·8	56·6	27·2	40	3·32	...	...	12	20	1	10	SE	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	77·2	98	28	51	10	88·0	66·4	21·6	30	5·96	...	...	5	22	5	4	SW	Charles Moore, D.D.S
Montgomery,	Skippack,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B. W. Dambly.
Northampton,	Easton— Lafayette College,	325	75·5	95	20, 29	49	10	86·8	64·2	22·6	32	0·53	...	...	8	17	10	4	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	77·4	102	20	47	10	91·3	63·6	27·7	40	2·39	...	...	10	22	7	2	W	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	78·0	97	28	58	8	86·8	68·7	18·1	24	0·75	...	...	7	12	12	7	SW	L. M. Dey, W. B
Philadelphia,	1529 Centennial Avenue,	120	78·1	98	29	56	10	87·8	68·4	19·4	26	0·65	...	...	6	11	15	5	SW	John Comly.
Philadelphia,	3911 Locust Street,	100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. L. Paddock.
Pike,	Blooming Grove,*[1]	...	73·3	101	28	54	9	...	...	...	...	3·66	...	...	10	6	21	4	S	John Grathwohl.
Potter,	Shingle House,	1,475	67·9	94	18	40	6	82·3	53·5	28·8	41	3·46	...	...	10	18	8	5	W	C. D. Voorhees, M.D.
Schuylkill,	Girardville,	1,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. C Wagner.
Snyder,	Selins Grove,	455	76·4	98	19	54	9, 14	91·4	61·5	29·9	43	1·20	...	...	5	...	26	5	SW	J. M. Boyer,
Somerset,	Somerset,	2,250	71·1	97	20	38	9	81·2	61·0	20·2	41	3·50	...	...	6	14	11	6	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	67·5	94	19	40	10	...	...	...	...	3·88	...	...	10	9	15	7	SW	H. D. Deming
Union,	Lewisburg,	450	74·4	100	19	42	10	88·4	60·4	28·0	44	1·36	...	...	7	21	1	9	SW	Prof. W. G. Owens
Wayne,	Dyberry,	1,100	69·4	96	20, 28	40	10	84·1	54·7	29·4	41	1·26	...	...	6	14	13	4	W	Theodore Day.
Wayne,	Honesdale,	1,000	71·7	93	29	48	10	82·6	60·8	21·8	30	0·71	...	...	8	23	2	6	W	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	73·0	95	20	47	10	82·8	63·2	19·6	31	1·24	...	...	0	10	11	9	W	T.B. Orchard, M D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	73·9	95	20	49	9	83·8	64·0	19·8	27	3·24	...	...	8	...	...	...	...	Murray Forbes
Westmoreland,	Ligonier,	1,750	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. D. Ambrose.
Wyoming,	South Eaton,	660	72·3	95	20	45	10	83·8	60·8	23·0	34	1·98	...	...	7	18	10	3	SW	B. M. Hall.
York,	York,	385	75·2	98	20	47	10	87·5	62·8	24·7	34	2·22	...	...	5	19	9	3	NW	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean temperature 8 + 8 ÷ 2.
‡ From 15th to 26th inclusive maximum temperature obtained from current readings.

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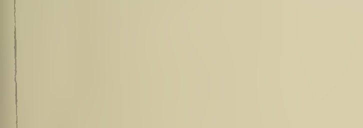


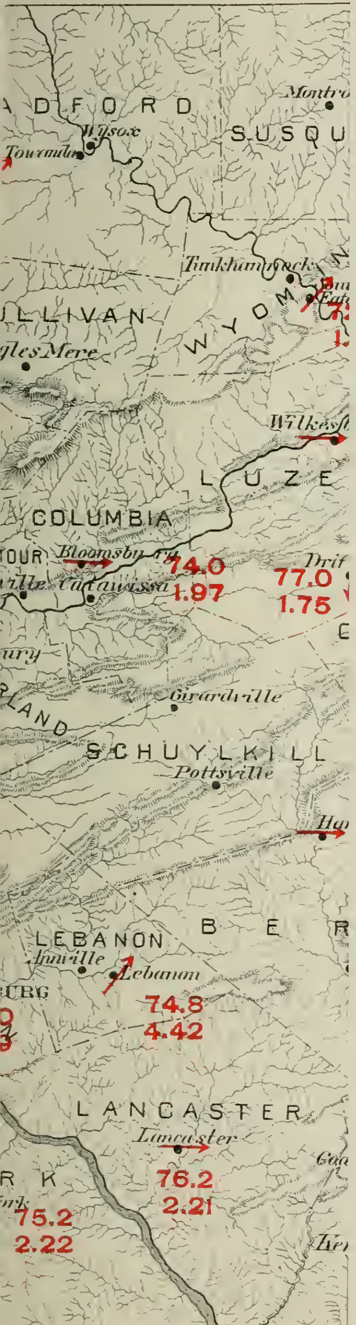
PRECIPITATION DURING JULY, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,				·03		·16							·03	·41	·38	·24						·94					·11	1·00	·36			3·66
Brewers Lock,						2·03										·18					·08			·41							1·13	3·83
Coatesville,						1·99								·20		·10					1·90	·02	·03	·30							·07	4·61
Coopersburg,	·12					·57	·23									·02					·84	·55		·15		·13	·04					2·65
Doylestown,						·89										·34					·07			·33						·19	·24	2·06
Dyberry,													·13		·04	·57						·26		·11					·15			1·26
Easton,	·01					·24									·01						·01		·11	05		·08			·02			0·53
Forks of Neshaminy,			·08			1·31									·03	2·83					·07			·49					·09		1·02	5·92
Frederick,			·05			1·85								·03		1·47					·23			·35								3·98
Hamburg,						·28	·46									·77					·47		·37	·49					·10		·08	3·02
Honesdale,							·03					·02		·05	·15	·04						·23		·07					·12			0·71
Kennett Square,						1·01								·20		1·28					·65	·10		·69				·02		·09		4·04
Lansdale,						1·56										·77					·21		·26						·11		·28	3·19
Mauch Chunk,						·09	·08									·15					·05	·05		·30		·31	·56		·30	·23		2·12
Ottsville,						1·15									·06						·91	·08		·14				·07				2·41
Philadelphia, a†						·11										·02	·15				·14	·08		·22						·03		0·75
Philadelphia, b,						·15										·03	·03				·17	·07		·20								0·65
Philadelphia, c,																																
Phoenixville,						1·80								·15		·32					·27	·02	·15	·33							·02	3·06
Point Pleasant,		·19				·74										·27				·38				·18						·06	·30	2·12
Pottstown,						2·97										·10					2·10			·52							·27	5·96
Quakertown,			·02			1·46															·19			·25		·03					·02	1·97
Reading,						·59	·01							·12		·87						·05	·01	·72							·01	2·39
Salem Corners,		·08			·03		·15	·01				·10				·17						·34		·10			·20			·06		1·24
Seisholtzville,						·59	·03															·12		·29		·07					·78	1·88
Skippack,																																
Smith's Corner,			·05			·93										·43					·96	·03		·20							·03	2·63
Swarthmore,						·49								·06		·43						·09		·33							·64	2·04
West Chester,						2·24								·05		·43					·24	·02		·48				·14		·22	·04	3·86
Westtown,																																
Susquehanna Basin.																																
Altoona,		·12												·01							·20		·05	·63								1·01
Aqueduct,		·04	·24			·05	·03							·02							·01		·32	1·20				·12	·30			2·39
Bloomsburg,						·85																·20		·27					·65			1·97
Carlisle,						·17											·03					·42	·30	·81	·23							1·96
Drifton,	*			*		·45	·34	*						·76	*	·20						*							*			1·75
Emporium,	·09															·14				·39	·22		·16	·71					·38			2·09
Gettysburg,						·26											·05						·11	·72	·33							1·47
Girardville,																																
Grampian,	·03	·72				·13														2·06	·09		·37	·38				·08	·20			4·06
Harrisburg.†			·19			·36								·08								·07	·33	·86								1·89
Hollidaysburg,			·23	*	*	*	*	*	*	*	*	*	*	·12	*	*				·31	·31		·77	·21					·08			2·03
Huntingdon,																					·12		·23	1·07					·15			1·57
Kilmer,						·21															·04		·17		1·54							1·96
Lancaster,						·55																		‡1·30							·36	2·21
Lebanon,	·04					1·88	·10							·12			·29				·02	·43	·05	1·49								4·42
Le Roy,				·08			·01	·02				·02			·05	·33	·05			·38	·72	·01	·03	·62	·02	·27			·37			2·98
Lewisburg,						·16	·02													·08			·14	·86	·04					·06		1·36
Lock Haven,				·01		·28																		1·01		·66		·45	·45			2·86
Selins Grove,																					·16	·01	·13	86	·04							1·20
South Eaton,							·08									·09					·28	·17		·30			·40		·66			1·98
State College,	·07		·02				·07													·17	·03		·54	·71				·27	·22			2·10
Wellsboro,														·02	·24		·05			·90	·05		·05	1·00	·02			1·05	·50			3·88
Wilkes-Barre,						·18										·22					·15			·10				·05		·04		0·74
York,						1·01								·03								·05	·42	·71								2·22

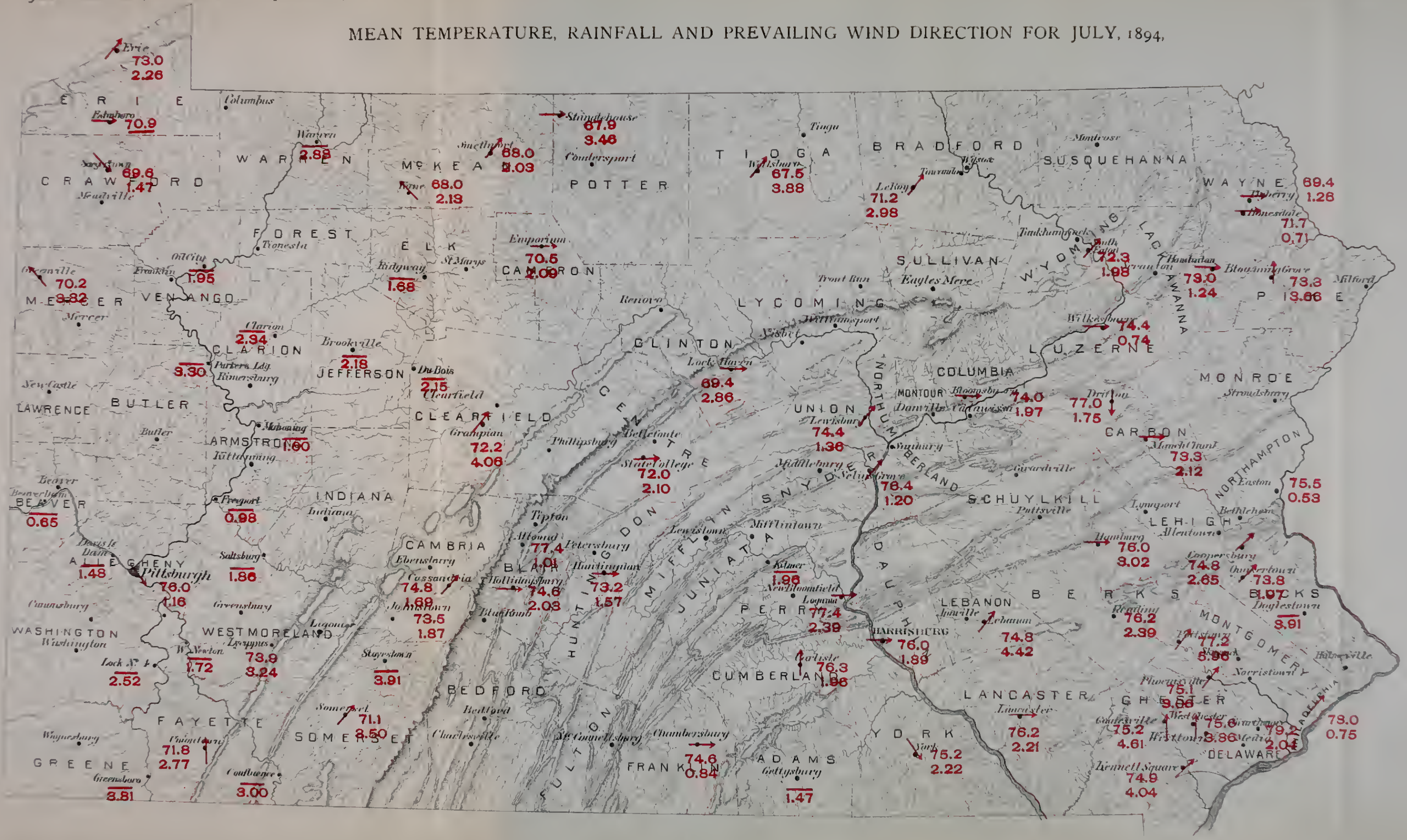
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,							·05																·04	·08	·20					·28		[illegible]
Brookville,			·14											·03				·07			1·04	·06		·33						·51		[illegible]
Cassandria,		·06		·01										05						·08			·51	·42					·13		·43	[illegible]
Clarion,			·60		·02							·01		·52										·30	·10					·79		[illegible]
Confluence,			·11		·79		·14							·01	·12						·32	·27	·02	·83			·09			·10		[illegible]
Davis Island Dam,			·28		·03		·02	·50	·13													·06	·01	·14	·12					·18		[illegible]
DuBois,		·91			·02							·02		·04							·23	·03	·05	·47	·36			·02				[illegible]
Elwood Junction,		·05	1·42				·05					·20		·09						·05			·03	·01						·10		[illegible]
Freeport,			·32				·03							·15										·28	·14					·16		[illegible]
Greensboro,	·60		·50		·20		·50							·10	·38							·35	·04	·32	·23					·35	·00	[illegible]
Greenville,		·05									·01		·28	·92			·01			·35	·29		·10	·18	·16			·06	·82			[illegible]
Immel Reservoir,	·60		·22											·25							·37			·70	·23				·62	·25		3·24
Indiana,																																
Johnstown,			·17											·11						·07	·22		·80	·36					·10	·14		[illegible]
Kane,		·03												·27	·09	·08				·72	·20		·04	·38					·32			[illegible]
Ligonier,																																
Lock No. 4,		·01	·23		·07		·22							·20				·02				1·09		·10	·33					·25		2·52
Mahoning,		·03	·47											·08							·23	23		·29	·08	·03				·16		[illegible]
Meadville,																																
Oil City,	·06		·19											·62		·02					·53	·12		·12	·09					·20		1·95
Parker's Landing,	·01	1·12	·50											·24				·23		·13	·15	·08		·14	·20	·04				·46		3·30
Pittsburg,†		·18	·38			·12	·01				·06			·10				·01			·01		·03	·12				·05	·19			[illegible]
Ridgway,		·08	·72											·08						·05			·10	·25						·40		[illegible]
Saegerstown,		·40					·02							·09	·40						·30			25	·20			·01				[illegible]
Saltsburg,												·02		·02							·05	55		·32	·25				·02	·48	·15	[illegible]
Shingle House,						·17	·06				·13			·54	·02					1·23	·60			·53	·03				15			[illegible]
Smethport,										·10				·13						·80				·40	·20				·30			[illegible]
Somerset,		·12												·10						1·35	·88	·15	·90									[illegible]
Stoyestown,			·10																		1·32	29	·35	·87		·21			·26	·51		3·91
Uniontown,			·37	·39		·08								·44				·04		·21	·11		·05	·33					·26	·39		[illegible]
Warren,			·01		·02									·53		·31					1·03	·20		·21	·10	·40				·07		[illegible]
West Newton,			·34									·03		·20								·50		·15	·15					35		[illegible]
Potomac Basin.																																
Chambersburg,					·05																		·12	·67								0·84
Lake Basin.																																
Erie,†		·02	·18	·04																	1·55			·24	·04				·19			2·26

† U. S. Weather Bureau Stations. * Missing. ‡ Total rainfall from 22d to 24th, inclusive.

IRECTION FOR JUL



MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR JULY, 1894.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. Townsend, Weather Bureau, Observer in Charge.

MONTHLY WEATHER REVIEW.

For August, 1894.

Hall of the Franklin Institute,
Philadelphia, August 31, 1894.

GENERAL REVIEW.

The average temperature for August, 1894, 69°·4, is the same as the average for the past six years.

The highest recorded temperatures occurred on the 1st, 2d, 8th, and 24th, and were as follows: Huntingdon, 98°; Logania, 97°; Hollidaysburg, 97°; Selins Grove, 96°; Hamburg, 95°; Johnstown, 95°; Saegerstown, 95°; Carlisle, 95°, and Lewisburg, 95°.

The lowest were on the 5th, 11th, 17th, 22d and 23d. Lock Haven, 32°; Wellsboro, 33°; Shingle House, 35°; Dyberry, 37°; Saegerstown, 38°, and Smethport, 39°.

The drought which began in July continued throughout the entire month and seriously affected growing crops. Many small streams were dried up and the larger ones lower than for many years.

From January 1, 1894, to August 31, 1894, the accumulated excess in daily mean temperature at Philadelphia was 428°; at Erie, 534°, and at Pittsburgh, 512°.

For the same period the deficiency in precipitation at Philadelphia was 4·97; Erie, 6·53, and Pittsburgh, 8·97.

TEMPERATURE.

	Mean Temperature.	Mean Precipitation, Inches.
August, 1888, ...	69°·5	7·05
1889, ...	67°·4	3·24
1890, ...	68°·4	5·76
1891, ...	69°·7	5·09
1892, ...	71°·3	3·77
1893, ...	70°·2	4·50
1894, ...	69°·4	1·84

The means of the daily maximum and minimum temperatures, 81°·4 and 57°·4, respectively, give a monthly mean of 69°·4, which is 0°·8 below the corresponding month of 1893.

The average daily range was 24°·0.

Highest monthly mean, 74°·0 at Pittsburg.

Lowest monthly mean, 61°·5 at Wellsboro.

Highest temperature recorded during the month, 98° on the 2d at Huntingdon.

Lowest temperature, 32° on the 12th and 22d at Lock Haven.

Greatest local monthly range, 61° at Lock Haven.

Least local monthly range, 31° at *Philadelphia* [Weather Bureau].

Greatest daily range, 54° at Lock Haven.

PRECIPITATION.

The average precipitation for the State, for the month, 1·84 inches, is 3·06 inches less than the average [4·90] for the last six years.

The rains were light and local in character. A few localities only received an average, and many not enough to be of much benefit.

The largest monthly totals were Lock Haven, 5·51; Chambersburg, 4·79; Lebanon, 4·17; Harrisburg, 4·08; Altoona, 3·18, and Smethport, 3·15.

The least were Freeport, 0·17; Mahoning, 0·30; Elwood Junction, 0·39; Brookville, 0·40; Oil City, 0·41, and Pittsburg, 0·43.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 6; clear days, 13; fair days, 12; cloudy days, 6.

BAROMETER.

The mean pressure for the month, 30·03, is about 0·5 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·27 at Pittsburg on the 5th, and the lowest 29·74 at Erie on the 2d.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Hollidaysburg, 1st, 2d, 12th, 13th; Le Roy, 15th; Quakertown, 1st, 2d, 3d, 18th, 19th; Cassandria, 1st, 2d, 13th, 19th, 26th; Johnstown, 13th, 19th, 26th; Emporium, 1st, 15th; State College, 13th, 15th, 19th; West Chester, 2d, 15th; Coatesville, 2d, 3d, 9th, 15th, 19th; Kennett Square, 15th, 18th; Lock Haven, 1st, 9th, 13th, 15th, 19th; Bloomsburg, 1st, 9th, 15th; Carlisle, 1st, 19th; Harrisburg, 1st, 2d, 13th, 19th; Uniontown, 9th, 12th, 13th, 15th, 19th, 26th; Lancaster, 2d; Lebanon, 1st, 9th, 15th, 19th, 20th; Coopersburg, 1st, 2d, 13th, 15th, 20th; Wilkes-Barre, 2d, 13th, 16th, 18th; Easton, 1st, 2d, 13th, 15th, 19th; Aqueduct, 1st, 2d; *Philadelphia* [Weather Bureau], 2d, 13th, 15th, 18th, 19th, 20th; [Centennial Avenue], 2d, 13th, 15th, 18th, 19th, 20th; Blooming Grove, 2d, 15th, 18th, 19th; Shingle House, 1st, 2d; Somerset, 13th; Lewisburg, 13th; Dyberry, 2d, 3d, 9th, 15th, 18th, 19th, 20th; Salem Corners, 1st, 2d, 3d, 9th, 13th, 15th, 19th; South Eaton, 1st, 2d, 9th, 13th, 15th, 19th; York, 1st, 2d, 15th, 18th.

Hail.—Coatesville, 15th; Lock Haven, 1st, 13th, 15th, 19th; Shingle House, 2d; York, 1st.

Frost.—Cassandria, 5th, 6th; Lock Haven, 12th, 13th, 22d; Wilkes-Barre, 21st; Shingle House, 11th; Somerset, 4th, 5th; Wellsboro, 6th, 11th, 17th, 22d; Dyberry, 10th, 11th.

Aurora.—Phœnixville, 9th.

Solar Halo.—Philadelphia [Weather Bureau], 26th; [Centennial Avenue], 4th.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR AUGUST, 1894.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR AUGUST, 1894.

COUNTY.	STATION	Elevation above Sea Level (feet).	TEMPERATURE.									PRECIPITATION.				NUMBER OF DAYS.			Wind.	OBSERVERS
				MAXIMUM.		MINIMUM.				DAILY RANGE.										
			Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.	Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.	Prevailing Direction.	
Allegheny,	Pittsburgh,	820	74·0	93	8	51	5	84·2	63·2	21·0	30	0·43	...	...	5	14	13	4	N	O. D. Stewart, W B
Berks,	Hamburg.	380	71·4	95	8	48	22	83·7	59·0	24·7	37	2·24	...	...	4	6	21	4	W	William Shipe.
Berks,	Reading,[2]	280	70·6	...	...	...	...	...	...	...	...	2·84	...	...	10	...	...	...	...	Franklin Yager.
Blair,	Altoona (29 days),	1,181	72·6	92	8	53	22	83·1	62·2	20·9	33	3·18	...	...	7	...	...	...	...	Dr. C. B. Dudley.
Blair,	Hollidaysburg (26 days),	947	68·5	97	8	41	5	84·6	52·4	32·2	46	2·47	...	...	6	19	3	4	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	66·7	89	24	47	21, 22	76·8	56·6	20·2	31	1·23	...	...	6	11	17	3	SW	G. W. T. Warburton.
Bucks,	Forks of Neshaminy,[1]	304	70·9	...	...	...	...	...	...	...	...	2·17	...	...	9	11	16	4	W	J. C. Hilsman.
Bucks,	Quakertown,	536	69·3	91	1, 8	45	22	81·6	57·0	24·6	36	3·09	...	...	8	9	20	2	SW	J. L. Heacock.
Cambria,	Cassandria	2,100	70·0	87	8	46	5	77·3	62·8	14·5	28	2·37	...	...	7	10	19	2	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	71·1	95	8	45	5	85·0	57·2	27·8	40	1·20	...	...	6	2	27	2	...	E. C. Lorentz.
Cameron,	Emporium,	1,050	66·4	89	8	43	11, 22	79·4	53·5	25·9	38	1·37	...	...	7	12	16	3	SW	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	68·8	94	8	44	22	82·1	55·6	26·5	40	1·86	...	...	6	16	9	6	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	69·0	91	8	47	22	79·6	58·3	21·3	32	2·23	...	...	9	8	9	14	W	Prof. Wm. Frear.
Chester,	West Chester,	455	70·9	88	8	52	22	79·4	62·4	17·0	24	1·86	...	...	7	17	4	10	S	J. C. Green, D.D.S.
Chester,	Coatesville,	380	70·6	90	1, 8	48	22	81·1	60·0	21·1	33	2·89	...	...	7	17	12	2	S	W. T. Gordon.
Chester	Kennett Square,	275	70·7	89	8, 16	48	22	81·2	60·2	21·0	30	2·78	...	...	9	13	11	7	SW	B. P. Kirk.
Chester,	Phœnixville,	190	71·2	90	8	48	22	81·5	61·0	20·5	33	1·64	...	...	7	10	7	14	NW	Knowles Croskey.
Chester,	Westtown,	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	John D. Carter.
Clearfield,	Grampian,	1,450	69·0	88	7	48	4, 31	81·6	56·5	25·1	34	1·15	...	...	6	10	20	1	SW	Nathan Moore.
Clinton,	Lock Haven,	560	63·3	93	8	32	12, 22	85·8	40·8	45·0	54	5·51	...	...	8	20	8	3	W	Prof. J. A. Robb.
Columbia,	Bloomsburg— State Normal School,	500	69·6	92	8	46	22	82·4	56·7	25·7	40	2·33	...	.	5	9	8	14	W	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,	1,200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prf. J. H. Montgomery.
Crawford,	Saegerstown,	1,200	66·1	95	1	38	17	83·8	48·4	35·4	51	0·98	...	...	5	8	17	6	N	J. G. Apple.
Cumberland,	Carlisle,	480	71·4	95	8	48	5, 22	82·7	60·2	22·5	35	2·92		...	7	16	12	3	SW	J. E. Pague.
Daupbin,	Harrisburg,	480	71·0	90	8	54	22	80·0	62·0	18·0	25	4·08	...	...	9	9	12	10	N	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	361	72·2	89	1	53	22	80·7	63·6	17·1	26	2·63	...	...	7	13	13	5	...	Prof. S. J. Cunningham
Erie,	Edinboro,*[1]	190	66·8	88	1	44	22	...	...	...	...	...	...	...	...	...	...	...	W	C. F. Sweet.
Erie,	Erie,	1,400	69·0	88	29	52	22	77·0	61·0	16·0	30	0·54	...	...	6	10	12	9	S	P. Wood, W. B.
Fayette,	Uniontown,	681	71·0	92	1, 9	45	5	82·6	59·5	23·1	36	1·42	...	...	7	19	7	5	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	70·4	93	8	48	22, 23	82·3	58·5	23·8	38	4·79	...	...	8	8	9	14	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	69·5	98	2	42	6	85·4	53·6	31·8	43	1·26	...	...	5	17	3	11	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker.
Lancaster,	Lancaster (17 days)— Franklin and Marshall Col'ge,	413	72·5	92	8	50	24	85·2	59·8	25·4	37	1·36	...	...	2	10	7	0	W	W. E. Bushong.
Lebanon,	Lebanon,	458	69·7	90	1	47	22	81·3	58·1	23·2	33	4·17	...	...	9	13	7	11	NE	G. W. Hayes, C. E
Lehigh,	Coopersburg,	520	70·5	87	8	50	22	79·5	61·4	18·1	29	2·43	...	...	9	16	12	3	NE	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	69·8	92	1	51	30	80·8	58·8	22·0	28	1·15	...	...	4	11	9	6	E	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	70·0	92	24	43	11, 22	84·9	55·2	29·7	41	1·14	...	...	6	16	13	2	W	A. W. Betterly.
McKean,	Kane,	2,000	65·8	88	24	41	17	77·9	53·6	24·3	38	1·45	...	...	7	17	12	2	SE	C. H. Kemp.
McKean,	Smethport,	1,500	64·8	88	24	39	17, 22	79·4	50·1	29·3	45	3·15	...	..	5	17	7	7	SE	Armstrong & Brownell.
Mercer,	Greenville— Thiel College (24 days)	1,000	67·0	91	1, 2	42	22	82·0	52·0	30·0	41	0·54	...	...	1	20	2	2	...	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	71·6	90	1	51	22	82·0	61·1	20·9	32	2·01	...	...	8	11	17	3	SW	Charles Moore, D.D.S
Montgomery,	Skippack,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B. W. Dambly.
Northampton,	Easton— Lafayette College,	325	70·6	89	1, 8	53	23	81·0	60·2	20·8	32	2·04	...	...	8	13	9	9	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	72·0	97	8	42	5	84·7	59·4	25·3	40	2·67	...	..	8	16	10	5	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	73·0	89	1	58	22	81·4	64·5	16·9	23	2·15	...	...	7	11	12	8	SW	L. M. Dey, W. B
Philadelphia,	1529 Centennial Avenue,	120	72·4	90	1, 3	55	22	81·3	63·4	17·9	25	2·57	...	...	8	11	14	6	SW	John Comly.
Philadelphia,	3911 Locust Street,	100		...	...	...	...	...	...	...	...	.	...	.	...	.	...	...	...	R. L. Paddock.
Pike,	Blooming Grove,*[1]	...	67·5	93	7, 24	50	22	...	...	..	..	1·62	...	...	5	2	22	7	S	John Grathwohl.
Potter,	Shingle House,	1,475	63·8	89	24	35	11	79·0	48·6	30·4	46	2·50	...	...	4	14	13	4	W	C. D. Voorhees, M D
Schuylkill,	Girardville,	1,000	...	...	...	...	...	.	.	.	...	...	...	...	...	...	...	...	...	E. C. Wagner.
Snyder,	Selins Grove,	455	69·4	96	6	42	23	85·2	53·6	31·6	47	2·47	...	...	9	22	..	9	SW	J. M. Boyer,
Somerset,	Somerset,	2,250	68·4	92	24	40	5	82·1	54·8	27·3	40	1·05	...	...	3	6	19	6	SE	W. M. Schrock
Tioga,	Wellsboro,*[1]	1,327	61·5	87	8	33	6, 17	.	...	...	...	2·05	...	...	6	13	10	8	N	H. D. Deming
Union,	Lewisburg (28 days),	450	70·0	95	8	46	5, 11	83·4	56·6	26·8	41	2·17	...	...	8	12	8	8	SW	Prof. W. G. Owens
Wayne,	Dyberry,	1,100	64·6	90	24, 25	37	11	80·1	49·1	31·0	48	1·27	...	...	7	14	12	5	W	Theodore Day.
Wayne,	Honesdale,	1,000	66·2	88	24	44	11	77·6	54·8	22·8	41	1·53	...	...	7	17	8	6	NW	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	67·6	86	1, 8	46	11	77·2	58·0	19·2	33	1·57	...	...	8	8	17	6	W	T.B. Orchard, M D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	72·0	91	9	49	4	81·9	62·2	19·7	30	1·09	...	...	4	...	...	...	...	Murray Forbes
Westmoreland,	Ligonier,	1,750	...	.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. D. Ambrose.
Wyoming,	South Eaton,	660	67·0	87	24	45	11	78·2	55·7	22·5	37	2·22	...	...	7	22	7	2	NW	B. M. Hall.
York,	York,	385	70·3	93	8	51	22	81·4	59·2	22·2	34	2·93	...	...	8	14	9	8	NW	Mrs. L. H. Grenewal

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 2.

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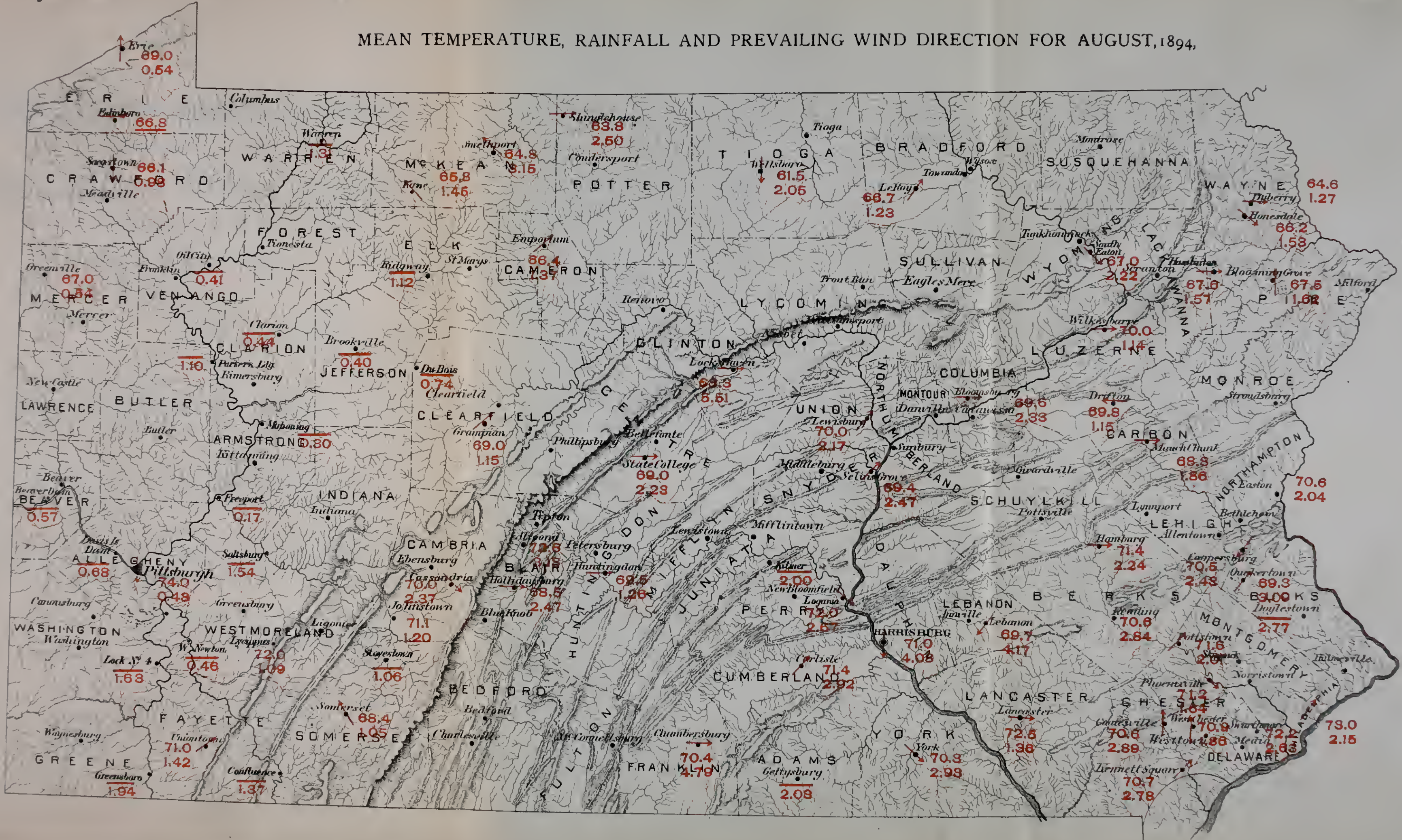
PRECIPITATION DURING AUGUST, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,		·50						·09				·36			·50				·17													1·62
Browers Lock,			·73	·06								·38								·07												1·24
Coatesville,		·25	·26	·06					·06			·74			·67					·55												2·89
Coopersburg,		·17	·56						·03			·23	·11		·66			·24	·01	·42												2·43
Doylestown,		·52	1·08									·44	·22		·17			·31		·03												2·77
Dyberry,		·25	·17						·21			·19			·16				·20	·09												1·27
Easton,		·09	1·30	·01					·02				·50		·01			·01		·10												2·04
Forks of Neshaminy,		·03	·56	·18								·35	·39		·18	·12		·01		·35												2·17
Frederick,		·77	·35	·03								·33	·28					·24		·75												2·75
Hamburg,		·40	·35									·52								·97												2·24
Honesdale,		·11	·23						·20			·25	·25		·41					·08												1·53
Kennett Square,			·78	·06					·04			·90	·02		·34	·02		·44		·18												2·78
Lansdale,	·04	1·17	1·00									·25	·40							·24												3·10
Mauch Chunk,		·22	·46						·07			·36			·53					·22												1·86
Ottsville,		·29	·61									·16			·51			·36														1·93
Philadelphia, a†			·80	·17								·39	·12		·01			·45		·21												2·15
Philadelphia, b.			·66	·29					·01			·50	·29		·01			·47		·34												2·57
Philadelphia, c,																																
Phœnixville,			1·02						·02			·03	·41		·03			·09		·04												1·64
Point Pleasant,	·19	·06	·13									·40			·22			·30														1·30
Pottstown,	·02	·80	·20	·08					·07			·36						·13														2·01
Quakertown,	·47	·15	·42	·03								·41	·35					1·08														3·09
Reading,	·01	·36	·17	·07					·01			·40	·01		·01			·01		1·79												2·84
Salem Corners,		·01	·37						·15			·35	·05			·40		·04		·20												1·57
Sensholtzville,	·49		·51									·20	·09							·37												1·72
Skippack,																																
Smith's Corner,		·13	·33	·04								·21	·04		·59			·38	·07	·04												1·83
Swarthmore,			·64	·69								·44						·26	·26	·16						·18						2·63
West Chester,			·70	·12					·05			·49			·13			·28		·09												1·86
Westtown,																																
Susquehanna Basin.																																
Altoona,		·33	·71				*			*		1·10	·37			·02				·62	·03											3·18
Aqueduct,	·02	1·64	·05						·04			·52	·04						·21	·15												2·67
Bloomsburg,		1·06	·56						·03			·52								·16												2·33
Carlisle,		1·50	·15						·05			1·10	·05		·02					·05												2·92
Drifton,	·20				*						·35	*							*	·53	·07		*								*	1·15
Emporium,	·35	·18							·10			·42	·05						·22	·05												1·37
Gettysburg,			·17									·78	·64	·04						·29							·11					2·03
Girardville,																																
Grampian,	·04								·06	·05		·64			·06					·30												1·15
Harrisburg,†	·07	2·28	·25						·04	·02		·53	·24	·01					·64													4·08
Hollidaysburg,		·04	·15									1·20	·73					*	·30	*	*	*				·05						2·47
Huntingdon,			·42									·45	·14							·16	·11											1·26
Kilmer,	·02	·28	·06						·03			1·05	·30		·10				·15						·01							2·00
Lancaster,		1·27							·09	*	*	*	*	*	*	*	*	*	*	*	*	*	*									1·36
Lebanon,	·06	·74	1·55						·15			·44	·01		·49				·05	·68												4·17
Le Roy,		·20	·43						·10			·08			·40					·02												1·23
Lewisburg,	·08	·80	·03						·11			·54	·03		·51						*	*	*		·07							2·17
Lock Haven,	1·20	1·22	·09									·40	·42		·65				1·46	·07												5·51
Selins Grove,	·03	1·12	·10					·06				·50	·19	·01	·30					·16												2·47
South Easton,		1·22	·12						·26			·28	·07		·17					·10												2·22
State College,	·03	·05	·23						·04			1·10	·15		·32				·25	·06												2·23
Wellsboro,		·10	·42						·10			·08			·20				1·25													2·05
Wilkes-Barre,		·30	·18								·20		·20			·16				·10												1·14
York,		·75	·15							·03		·67	·05		·33				·32	·63												2·93
Ohio Basin.																																
Beaver Dam,										·06									·35	·16												0·57
Brookville,		·26	·04							·04		·06																				0·40
Cassandria,	·14	·04										·62	1·05						·36	·03						·13						2·37
Clarion,			·30							·02		·11														·01						0·44
Confluence,			·09							·05		·12	·14	·44		·02				·41						·01	·09					1·37
Davis Island Dam,										·04	·01					·02			·03	·26							·32					0·68
DuBois,		·15							·07		·07	·24	·03							·10						·08						0·74
Elwood Junction,																			·22	·13						·04						0·39
Freeport,													·17																			0·17
Greensboro,			·20							·83		·18				·05			·10	·20						·15	·23					1·94
Greenville,													·54												*	*	*	*	*	*	*	0·54
Immel Reservoir,		·05											·67		·25					·32												1·29
Indiana,																																
Johnstown,												·21	·85		·31				·07	·04						·02						1·50
Kane,	·01	·72							·35			·21	·05		·08										·03							1·45
Ligonier,																																
Lock No. 4,		·05											·05			·20			·55	·28												1·13
Mahoning,		·21								·05									·03	·01												0·30
Meadville,																																
Oil City,			·06							·02			·20						·02	·12												0·42
Parker's Landing,			·65									·05	·17							·22						·01						1·10
Pittsburg,†		·01								·04		·01							·04	·33												0·43
Ridgway,		·14	·12						·04			·20	·50							·12												1·12
Saegerstown,		·55		·08					·03				·07					·25														0·98
Saltsburg,	·32	·02										·05	·95							·20												1·54
Shingle House,		1·73							·25			·21							·31													2·50
Smethport,	2·00	·55							·15			·25							·20													3·15
Somerset,													·70	·25				·10														1·05
Stoyestown,		·17										·05	·48	·05		·15				·07		·09										1·06
Uniontown,									·11	·03		·07	·04						·43	·02						[illegible]						1·42
Warren,		·25							1·05			·01																				1·31
West Newton,		·07	·03							·07			·02							·27												0·46
Potomac Basin.																																
Chambersburg,	·37	1·33	·25									1·77	·14		·47				·43	·03												4·79
Lake Basin.																																
Erie,†		·28	·01					·01	·05						·01				·18													0·54

† U. S. Weather Bureau Stations. * Missing.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR AUGUST, 1894.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. Townsend, Weather Bureau, Observer in Charge.

MONTHLY WEATHER REVIEW.

For September, 1894.

Hall of the Franklin Institute,
Philadelphia, September 30, 1894.

GENERAL REVIEW.

The average temperature for September, 1894, 66°·6, is 4°·5 above the average (62°·1) for the past six years.

The highest recorded temperatures occurred on the 2d, 3d, 10th, 11th and 15th, and were as follows: Saegerstown, 95°; Huntingdon, 94°, and 92° at ten stations.

The lowest were on the 25th and 26th. Shingle House, 24°; Lock Haven, 26°; Smethport, 28°, and Wellsboro, 28°.

The drought which began in July was broken September 8th, when general rains occurred. The effect of the drought on crops was very damaging in nearly all parts of the State.

From January 1, 1894, to September 30, 1894, the accumulated excess in daily mean temperature at Philadelphia was 498°; at Erie, 673°, and at Pittsburg, 635°.

For the same period the deficiency in precipitation at Philadelphia was 3·29; Erie, 5·19, and Pittsburgh, 7·92.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
September, 1888, ...	59°·0	4·84
1889, ...	61°·9	5·05
1890, ...	62°·0	4·57
1891, ...	66°·4	2·39
1892, ...	62°·3	2·81
1893, ...	60°·9	2·67
1894, ...	66°·6	6·30

The means of the daily maximum and minimum temperatures, 76°·8 and 56°·4, respectively, give a monthly mean of 66°·6, which is 5°·7 above the corresponding month of 1893.

The average daily range was 20°·4.

Highest monthly mean, 70°·0 at Pittsburg and *Philadelphia* [Weather Bureau].

Lowest monthly mean, 60°·6 at Wellsboro.

Highest temperature recorded during the month, 95° on the 2d at Saegerstown.

Lowest temperature, 24° on the 26th at Shingle House.

Greatest local monthly range, 68° at Shingle House.

Least local monthly range, 44° at Cassandria, Lancaster and Swarthmore.

Greatest daily range, 55° at Lock Haven.

PRECIPITATION.

The average precipitation for the State, for the month, 6·30 inches, is 2·58 inches more than the average [3·72] for the last six years.

Excessive rains occurred at 24 stations. On the 8th, 3·20 inches fell in 40 minutes at Bethlehem. On the 18th, at Smith's Corner, 7·70 inches fell in 12 hours, and 7·32 inches at Point Pleasant in 7 hours and 40 minutes.

The largest monthly totals were: Clarion, 12·36; Smith's Corner, 11·61; Point Pleasant, 10·67; Parker's Landing, 9·82; Carlisle, 9·45, and Brower's Lock, 9·27.

The least were: Chambersburg, 2·82; Somerset, 3·12; Davis Island Dam, 3·13; West Newton, 3·20; Confluence, 3·48, and Pittsburg, 3·68.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 10; clear days, 10; fair days, 10; cloudy days, 10.

BAROMETER.

The mean pressure for the month, 30·09, is about ·01 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·55 at Philadelphia on the 13th, and the lowest 29·70 at Philadelphia on the 19th.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Pittsburg, 7th, 9th, 13th; Hollidaysburg, 7th, 8th, 9th, 14th, 15th, 16th; Le Roy, 5th, 8th, 10th; Quakertown, 8th, 10th, 16th, 18th; Cassandria, 7th, 8th, 9th, 10th, 16th; Johnstown, 7th, 8th, 9th, 14th, 16th, 30th; Emporium, 7th, 8th, 10th, 15th, 16th; E. Mauch Chunk, 8th; State College, 9th; West Chester, 8th, 10th, 18th; Coatesville, 9th, 10th, 16th, 18th; Kennett Square, 8th, 9th; Westtown, 8th, 10th, 19th; Grampian, 8th; Lock Haven, 5th, 8th, 14th, 16th; Saegerstown, 6th, 7th, 10th, 12th, 15th; Carlisle, 8th, 17th, 18th; Harrisburg, 8th, 9th, 10th, 16th, 18th; Swarthmore, 8th, 9th, 16th; Uniontown, 6th, 7th, 9th, 10th, 14th, 16th, 19th; Huntingdon, 8th, 9th, 14th, 16th; Lancaster, 8th, 10th, 16th; Coopersburg, 8th, 10th, 16th, 18th;

Wilkes-Barre, 8th, 13th, 16th, 19th; Pottstown, 8th, 10th, 16th; Easton, 8th, 9th, 10th, 16th, 18th; Logania, 8th, 9th, 16th, 18th: *Philadelphia* [Weather Bureau], 8th, 9th, 10th, 18th; [Centennial Avenue], 8th, 9th, 10th; Blooming Grove, 8th, 10th, 14th, 16th; Somerset, 7th; Wellsboro, 5th, 8th, 10th, 15th, 16th; Lewisburg, 8th, 18th; Dyberry, 8th, 16th; Hamlinton, 8th, 10th, 16th; South Eaton, 8th, 10th, 16th; York, 8th, 9th, 10th, 16th, 18th; Lebanon, 8th, 9th, 10th, 16th.

Hail.—Cassandria, 10th; Pottstown, 8th; Phœnixville, 8th.

Frost.—Hollidaysburg, 26th; Le Roy, 26th; Quakertown, 26th; Cassandria, 12th, 25th, 26th; Johnstown, 24th, 25th; Emporium, 26th; East Mauch Chunk, 26th; State College, 26th; Coatesville, 25th, 26th; Grampian, 12th, 26th; Lock Haven, 12th, 24th, 25th, 26th; Saegerstown, 26th; Carlisle, 26th; Harrisburg, 26th; Edinboro, 26th; Uniontown, 25th; Huntingdon, 25th, 26th; Coopersburg, 12th, 26th; Drifton, 26th; Wilkes-Barre, 27th; Kane, 26th; Smethport, 25th; Logania, 26th; Blooming Grove, 25th, 26th; Shingle House, 12th, 26th; Selins Grove, 26th; Somerset, 25th, 26th, 30th; Wellsboro, 12th, 26th; Lewisburg, 26th; Dyberry, 12th, 13th, 25th, 26th; Honesdale, 26th; Hamilton, 26th; South Eaton, 26th; York, 26th; Phœnixville, 26th; Lebanon, 12th, 26th; Greenville, 26th.

Aurora.—Le Roy, 21st; Kane, 14th.

Solar Halo.—*Philadelphia* [Weather Bureau], 26th; [Centennial Avenue], 26th; Wellsboro, 18th.

Lunar Halo.—*Philadelphia* [Centennial Avenue], 11th; Wellsboro, 17th.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR SEPTEMBER. 1894.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for September, 1894.

County.	Station	Elevation above Sea Level (feet).	Temperature.									Precipitation.				Number of Days.			Wind.	Observers
			Mean.	Maximum.		Minimum.		Mean of Maximum.	Mean of Minimum.	Daily Range.		Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.	Prevailing Direction.	
				Highest.	Date.	Lowest.	Date.			Mean.	Greatest.									
Allegheny,	Pittsburgh,	820	70·0	92	3	43	26	79·3	61·4	17·9	35	3·68	. . .	. . .	11	9	11	10	SE	O. D. Stewart, W. B
Berks,	Hamburg.	380	68·2	90	10	42	26	77·8	58·6	19·2	32	6·25	. . .	. . .	7	9	14	7	E	William Shipe.
Berks,	Reading,[2]	280	65·6	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	7·48	. . .	. . .	16	. .	. .	. .	. . .	Franklin Yager.
Blair,	Altoona,	1,181	68·9	87	3, 4	40	26	76·8	61·0	15·8	29	5·25	. . .	. . .	11	. .	. .	. .	. . .	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	66·7	92	2	31	26	78·8	54·6	24·2	38	5·68	. . .	. .	13	12	8	10	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	64·1	90	2	32	26	73·2	55·1	18·1	32	5·44	. . .	. . .	10	11	10	9	SW	G. W. T. Warhurtoo
Bucks,	Forks of Neshaminy[1] (22 days),	304	69·4	. . .	. . .	. . .	.	. . .	. . .	. . .	. .	6·94	. . .	. . .	9	8	4	10	N	J. C. Hilsman.
Bucks,	Quakertown,	536	66·2	90	10	34	26	77·5	55·1	22·4	39	7·22	. . .	. . .	7	8	18	4	SW	J. L. Heacock.
Cambria,	Cassandria	2,100	66·8	84	2, 18, 3	40	26	72·9	60·6	12·3	31	5·25	.	. . .	12	6	18	6	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	68·7	94	2	37	26	80·2	57·2	23·0	42	5·44	. . .	. . .	15	8	13	9	. . .	E. C. Lorentz.
Cameron,	Emporium,	1,050	64·8	88	2	31	26	75·4	54·1	21·3	39	5·26	. . .	. . .	12	13	7	10	E	T. B. Lloyd.
Carhon,	E. Mauch Chunk,	550	65·8	91	2	32	26	76·2	55·4	20·8	42	5·63	. . .	. . .	9	13	8	9	S	F. C. Wintermute.
Centre,	State College (29 days)— Agricultural Experiment Sta.,	1,191	66·0	89	2	34	26	75·2	56·9	18·3	36	5·78	. . .	. .	10	6	9	14	S	Prof. Wm. Frear.
Chester,	West Chester,	455	68·2	90	10	41	26	75·7	60·6	15·1	24	6·84	. . .	. . .	8	11	4	15	S	J. C. Green, D.D.S.
Chester,	Coatesville,	380	68·0	91	10	37	26	77·8	58·1	19·7	34	8·42	. . .	. . .	6	11	12	7	S	W. T. Gordon.
Chester	Kennett Square,	275	68·4	91	10	40	26	77·8	58·9	18·9	29	7·71	. . .	. . .	9	12	3	15	NE	B. P. Kirk.
Chester,	Phœnixville,	190	68·3	91	10	37	26	77·2	59·4	17·8	33	8·31	. . .	. . .	7	9	6	15	SW	Knowles Croskey.
Chester,	Westtown (24 days),	350	66·4	89	10	40	26	74·2	58·5	15·7	28	5·83	. . .	. . .	6	9	3	12	W	John D. Carter.
Clearfield,	Grampian,	1,450	64·9	88	3	36	26	73·4	56·4	17·0	32	7·08	. . .	. . .	11	5	13	12	SW	Nathan Moore.
Clinton,	Lock Haven,	560	62·1	92	2	26	25	82·2	42·0	40·2	55	6·46	. . .	. . .	12	14	5	11	W	Prof. J. A. Robb.
Columbia,	Bloomsburg— State Normal School,	500	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	Prof. J. G. Cope.
Crawford,	Saegerstown,	1,200	63·8	95	2	30	26	78·8	48·7	30·1	53	6·14	. . .	. . .	12	12	9	9	N	J. G. Apple.
Cumberland,	Carlisle,	480	68·6	90	2	36	26	78·2	59·1	19·1	36	9·45	. . .	. . .	10	13	6	11	S	J. E. Pague.
Dauphin,	Harrisburg,	480	68·0	88	10	40	26	76·1	60·6	15·5	28	5·53	.	. . .	9	11	8	11	E	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	361	69·4	89	10	45	26	76·6	62·3	14·3	26	5·50	. . .	. . .	6	8	7	15	NE	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	64·6	90	3	33	26	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	17	8	5	NW	C. F. Sweet.
Erie,	Erie,	1,400	67·0	90	15	36	27	76·0	59·0	17·0	35	5·48	. . .	. . .	13	10	13	7	S	P. Wood, W. B
Fayette,	Uniontown,	681	68·8	92	8	40	25	78·6	58·9	19·7	32	5·77	. . .	. . .	10	11	14	5	SW	Wm. Hunt.
Franklin,	Chambersburg (29 days),	1,000	68·1	90	9	40	26	78·6	57·6	21·0	34	2·82	. . .	. . .	6	5	9	15	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	66·9	94	2	33	26	78·6	55·2	23·4	45	7·56	. . .	. . .	11	12	8	10	W	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	69·0	90	11	46	25	79·7	58·2	21·5	35	7·32	. . .	. . .	7	11	14	5	W	W. E. Bushong.
Lebanon,	Lebanon,	458	67·3	89	10	36	26	77·6	57·0	20·6	35	5·47	. . .	. . .	9	9	8	13	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	66·8	87	2	39	26	74·0	59·7	14·3	28	5·86	. . .	. . .	10	10	13	7	SE	Dr. M. H. Boye.
Luzerne,	Drifton (25 days),	1,683	65·6	85	6, 7	40	29	75·2	56·0	19·2	31	4·65	. . .	. . .	10	9	6	10	E	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	66·0	89	10, 15	32	26	77·7	54·2	23·5	38	5·05	. . .	. . .	9	13	10	7	W	A. W. Betterly.
McKean,	Kane,	2,000	63·2	89	2, 3	33	26	73·7	52·8	20·9	36	6·97	. . .	. . .	12	9	13	8	SW	C. H. Kemp.
McKean,	Smethport,	1,500	62·8	92	2	28	26	75·6	49·9	25·7	49	6·32	. . .	. . .	8	17	5	8	SE	Armstrong & Brownell.
Mercer,	Greenville— Thiel College (24 days)	1,000	62·8	92	8	35	26	76·0	49·6	26·4	48	6·03	. . .	. . .	12	8	5	11	. . .	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	67·9	87	2, 9	40	26	77·0	58·8	18·2	32	7·94	. . .	. . .	8	10	9	11	W	Charles Moore, D.D.S.
Northampton,	Easton— Lafayette College,	325	66·0	88	2	37	26	75·9	56·1	19·8	36	6·57	. . .	. . .	7	10	7	13	. . .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	69·5	92	9, 10	37	26	79·2	59·8	19·4	36	5·68	. . .	. . .	11	10	6	14	SE	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	70·0	91	10	44	26	77·2	62·7	14·5	21	5·11	. . .	. . .	8	10	6	14	SW	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	69·8	91	10	43	26	77·4	62·3	15·1	24	6·57	. . .	. . .	8	10	8	12	SW	John Comly.
Pike,	Blooming Grove,*[1]	. . .	63·5	89	2	30	26	. . .	. . .	. .	. . .	4·80	. . .	.	6	6	17	7	W	John Grathwohl.
Potter,	Shingle House,	1,475	62·4	92	2	24	26	76·1	48·6	27·5	49	5·96	. . .	. . .	11	10	8	12	W	C. D. Voorhees, M. D
Snyder,	Selins Grove,	455	64·8	90	3, 5	33	26	78·7	51·0	27·7	46	4·25	. . .	. . .	10	. .	23	7	SW	J. M. Boyer,
Somerset,	Somerset,	2,250	65·8	90	5, 15	34	26	79·0	52·5	26·5	42	3·12	. . .	. . .	8	4	17	9	NW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	60·6	88	2, 15	28	26	. . .	. . .	. . .	. . .	5·85	. . .	. . .	8	11	8	11	S	H. D. Deming
Union,	Lewisburg (28 days),	450	67·2	92	2	34	26	78·9	55·5	23·4	44	5·09	. . .	. . .	9	6	7	15	S	Prof. W. G. Owen
Wayne,	Dyberry,	1,100	62·3	88	10	26	26	75·2	49·4	25·8	42	4·40	. . .	. . .	10	13	10	7	NW	Theodore Day.
Wayne,	Honesdale,	1,000	63·7	83	10	30	26	73·1	54·3	18·8	32	4·47	. . .	. . .	15	12	9	9	W	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	64·6	87	5	31	26	73·3	56·0	17·3	30	5·67	. . .	. . .	12	6	12	12	W	T.B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	68·1	92	4	41	25	77·2	59·0	18·2	33	7·68	. . .	. . .	8	. .	. .	. .	. . .	Murray Forbes
Westmoreland,	Ligonier,	1,750	.	.	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	C. D. Ambrose.
Wyoming,	South Eaton,	660	64·6	87	2, 10	33	26	74·6	54·6	20·0	38	3·69	. . .	. .	9	17	6	7	NW	B. M. Hall.
York,	York,	385	68·2	91	10	39	26	78·0	54·8	19·6	34	9·16	. . .	. . .	10	10	10	10	NW	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean temperature 8 + 8 ÷ 2.

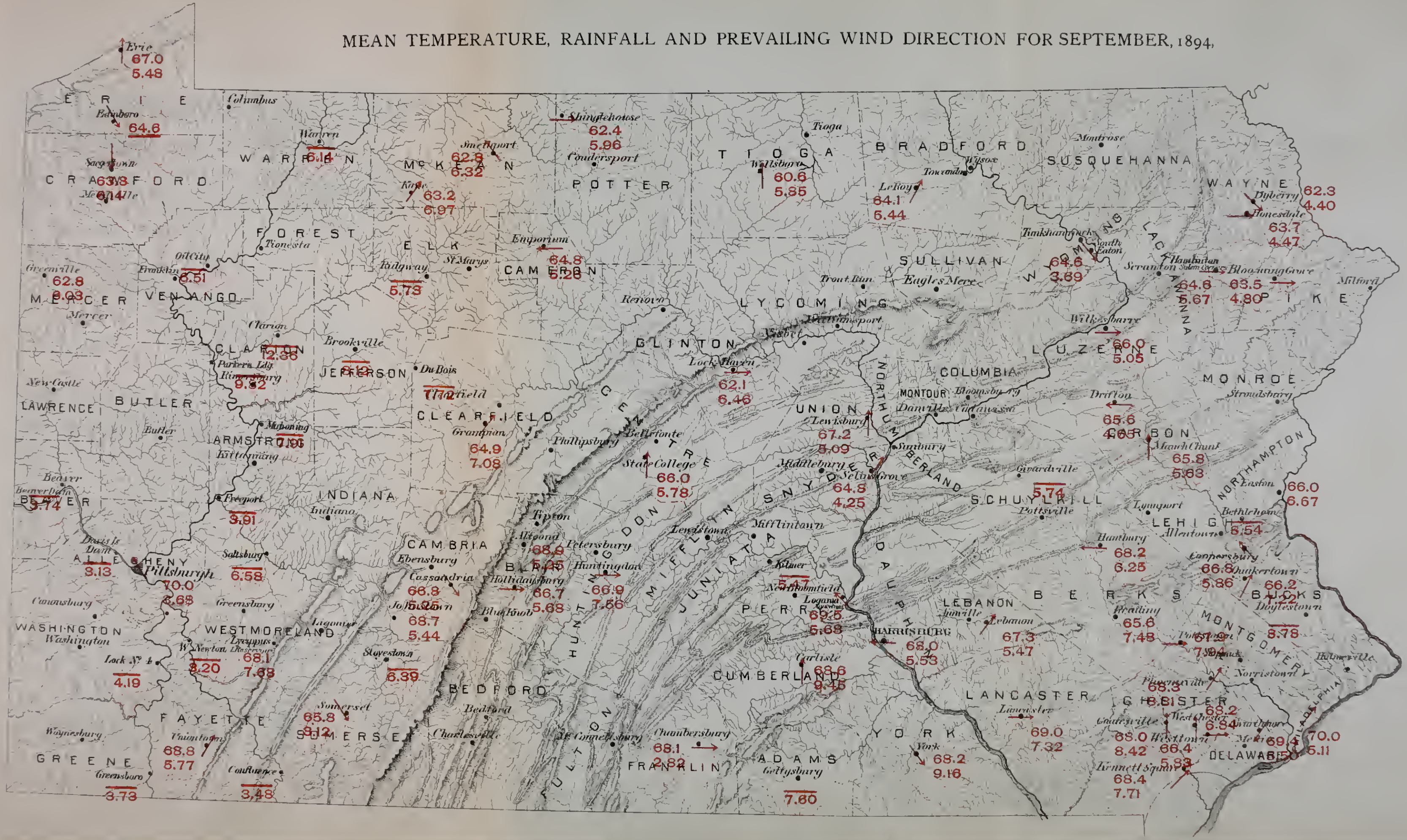
PRECIPITATION DURING SEPTEMBER, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Bethlehem,						·22		4·67		·91				·14		·11		1·16	1·33													8·54
Blooming Grove,							·60	·15		·27				·55		·29			2·94													4·80
Browers Lock,								·30	3·93		·39							3·17	1·48													9·27
Coatesville,								2·93	·76	·65						·09		·72	3·27													8·42
Coopersburg,						·77		1·21	·04	·66				·06		·31	·10	1·48	1·22										·01			5·86
Doylestown,						·02	4·00		·05	·44						·02		2·45	1·65	·15												8·78
Dyberry,						·72		·23		·35				·30	·17	·38		·13	1·87	·13			·12									4·40
Easton,						·02			1·15	·98					·19		·32		3·90											·01		6·57
Forks of Neshaminy,						·03		3·33	·22	·41				·04		·08		1·26	1·43	·14												6·94
Frederick,						·03	·06	2·51	·21	·49				·11		·05	·02	2·23	1·39											·02		7·12
Hamburg,						·44		1·24		·40				·13		·28		1·44	2·32													6·25
Honesdale,						·62		·47	·01	·47	·02		·01	·16	·05	·20	·17	·17	1·81	·16			·14	·01								4·47
Kennett Square,							·25	·04	2·80	·57							·11	1·32	2·60							·01	·01					7·71
Lansdale,							·83	3·60		·69					·21	·16		1·98		1·37												8·84
Mauch Chunk,						·03		1·11	·03	·25				·43		·07		·75	2·87	·09												5·63
Ottsville,						·29		1·00	·09	·72				·02		·36	·23	4·21	1·28	·04										·03		8·27
Philadelphia, a†					·01		·01	·82	1·14	·75								·55	1·13	·70												5·11
Philadelphia, b,					·01		·01	·89	1·68	·83								1·10	1·55	·50												6·57
Phœnixville,								2·98		·73				·05			3·00	1·50	·03											·02		8 31
Point Pleasant,						·12		95		·53						·21	05	7·32	1·49													10 67
Pottstown,						·07		4·17		·55				·07		·13		·80	2.15													7·94
Quakertown,						·40		1·64		·59						·53		2·78	1·23	·05												7·22
Reading,					·01	·04	·05	2·55	·20	1·01				·13	·02	·20	·20		·65	2·38	·01						·01	·01		·01		7 48
(Salem Corners)																																
Hamlinton,						·46		·41	·10	·02	·56			·50		·13	·60	·10	1·38	1·33				·08								5·67
Seisholtzville,						·48		1·06	·09	·63				·10		·14	·07	1·06	1·96	·01												5·60
Smith's Corner,						·17		·98	·03	·51				·05		·28	·21	7·70	1·55	·05										·08		11·61
Swarthmore,							·10	1·85	·44	·51	*								§2·60													5·50
West Chester,							·09	1·54	·70	·51							·06	1·96	1·97								·01					6·84
Westtown,	*	*	*	*			·07	1·95	*	·40							·04	1·45	1·92													5·83
Susquehanna Basin.																																
Altoona,						·15		·42	1·12	·66	·38			·10	·22	·45	·07		1·10	·58												5·25
(Aqueduct) Logania,							·46	·34	1·74	·22				·02		·50	·02	1·39	·96	·01							·02					5·68
Bloomsburg,																																
Carlisle,						·02	·90	2·00	1·20	1·28						·25	·10	2·40	1·10								·20					9·45
Driftoo,		*				·43	·31	·06	*	·37			·03	·95		·25		1·26	·49	·50			*							*		4·65
Emporium,							·05	·86	·15	·88			·11	·17	·10	·43		·30	1·76	·40										·05		5·26
Gettysburg,							·25	1·82	·17	·60							1·40	·52	2·50	·23									·11			7·60
Girardville,								1·59		·39				·27		·28		2·04	1·11	·06												5·74
Grampian,							·72	1·98	·11	·09			·13	·41		·34		·70	1·80	·18										·02		7·08
Harrisburg,†							·46	·72	·62	·52						·57	·02	1·32	1·26								·04					5·53
Hollidaysburg,							·05	·51	·73	·20			·05	·09	·13	1·29		1·23	1·25	·08			·05							·02		5·68
Huntingdon,						·13	·05	·58	2·83	·20				·55		·85	·10	·75	1·50	·02												7·56
Kilmer,							·20	1·60	·27	·11									‖3·27	·02												5·47
Lancaster,								‡2·74		·84						1·08			§2 66													7·32
Lebanon,							·71	·64	·44	·16				·05		·61	·01	·73	2·12													5·47
Le Roy,						·70		·52	·02	·86			·06	·08		1·02			1·90	·12			·16									5·44
Lewisburg,						·25	·15	1·23	·08	·46			·29		·69		·77	1·17				*	*									5·09
Lock Haven,					·44		·05	1·45	·24	·70				·60	·02	1·10	·11	·22	1·51	·02												6·46
Selins Grove,						·21	·23	·32		·45				·18		·30	·01	·93	1·50	·12												4·25
South Eaton,						·55		·20		·39	·04			·05		·34		·15	1·85	·12												3·69
State College,							·08	1·31	1·28	·27					·01	·61	·04	·45	1·61	·12					*							5·78
Wellsboro,					40			·75		1·20					·40	·35		·10	2·50	·15												5·85
Wilkes-Barre,						1·05		·17		·60			·27			·67		·36	1·57		·29		·07									5·05
York,							2·23	1·00	·80	·19					·20	2·60	·08	·89	1·15								·02					9·16

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,								·15	·31	·72	·36			·08		·20			·54	1·38												3·74
Brookville,								·52	2·27	·70	·65			·54	·41	·63	·03	·11	·67	1·41	·07											8·12
Cassandria,						·07	1·06	·34	·60	·50	·03					·34	·16	·41	1·42	·30							·02					5·25
Clarion,								1·76	2·31	·32	2·21		·07	·95	·77	1·14	·02	·12	·34	2·25	·07		·01	·02								12·36
Confluence,							·05	·45		·23	·48				·02	·38	·03		·81	·93	·10											3·48
Davis Island Dam,								·30		·14	·29		·01	·16	·06	·07	·03		·61	1·45	·01											3·13
DuBois,								1·15	1·27	·05	·70			·33	·60	·18	·01	·03	1·17	2·16	·07											7·72
Elwood Junction,								·20		1 11	·50		·04		·06	·10			·40	2·32	·10											4·83
Freeport,							·03	·41	·38	·07	·45		·18	·15	·27	·07	·03	·48	·28	·92	·17			·02								3·91
Greensboro,								·40		·25	·50			·20		·55	·06		1·00	·75	·02											3·73
Greenville,							·12	·18	·02	1·55			·50	·19	·32		·01	·57	·65	1·89		·03										6·03
(Immel Reservoir)																																
Lycippus,							1·80	1·07	·40	·57				1·00		·06			·70	2·08												7·68
Johnstown,						·02	·68	·65	·04	37			·05	·12	·17	·65	·16	·40	1·41	·64	·01									·05		5·44
Kane,							·27	·64	·06	1·06			·21	·49	·23	1·18	·03	·14	1·60	·46												6·37
Ligonier,																																
Lock No. 4,							·01	·35		·68	·36		·02	·02	·24		·08	·35	·56	1·42	·02									·08		4·19
Mahoning,								·42	·23	·51	1·04			·58		·26	·16	·58	·43	3·60	·08		·02									7·91
Oil City,								·31	1·05	·16	1·15		·09	·56	·08	·48	·03		·31	2·20	·06		·01	·02								6·51
Parker's Landing,								·32	·78	·10	1·07		·18	1·10	·50	·51	·01	·03	·30	4·81	·04			·07								9·82
Pittsburg,†							·49	·05	·30	43			·05	·01		·17		·64	·26	1·26										·02		3·68
Ridgway,								·96	·83	·41	1·01		·28		·16	·58				1·50												5·73
Saegerstown,					·05		·05	·60		1·70			·90	·15	·35	·40			·20	1·40			·26		·08							6·14
Saltsburg,						·10	·02	·70	·02	·10	·60		·02	1·33		·14	04		·82	2·48	·21											6·58
Shingle House,								1·48	·13	1·40			·06	·28	·10	·63		07	1·34	·39			·08									5·56
Smethport,								·75	·12	1·40				·40		1·50			1·65	·45			·05									6·32
Somerset,							·51		·56	·36			·01		·33			·60	·65	·10												3·12
Stoyestown,							·52	2·01	·37	·29	·60			·13	·17	·19	·26	·11	·60	·91	·23											6·39
Uniontown,							·07		·30	·78			·20	·05		1·05	·72	·94	·34	1·32												5·77
Warren,						·10		·91	·82	·05	·59			·19	·61	·91	·01		·64	·95	·03			·33								6·14
West Newton,								·20		·10	·27				·18			·17	·53	1·62	·13											3·20
Potomac Basin.																																
Chambersburg,							·14		·19	·11						·51		·92	·95						*							2·82
Lake Basin.																																
Erie,†					·76		·04	·28	·14	1·07			·49	·02	·10	·14			·48	1·68		·02	·26									5·48

† U. S. Weather Bureau Stations. * Missing. § Total rainfall for 18th and 19th. ‖ Total rainfall from 16th to 19th, inclusive. ‡ Total rainfall from 6th to 8th, inclusive.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR SEPTEMBER, 1894.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. Townsend, Weather Bureau, Observer in Charge.

MONTHLY WEATHER REVIEW.

For October, 1894.

Hall of the Franklin Institute,
Philadelphia, October 31, 1894.

GENERAL REVIEW.

The average temperature for October, 1894, 53°·6, is 4°·0 above the average [49°·6] for the past six years.

The highest recorded temperatures occurred on the 1st, 2d, 3d, 19th, 20th and 21st, and were as follows: Lock Haven, 88°; Chambersburg, 84°; Coatesville, 83°; Carlisle, 83°, and York, 83°.

The lowest were on the 12th, 15th, 16th, 18th, and 19th. Shingle House, 24°; Wellsboro, 24°; Saegerstown, 25°; Dyberry, 25°; Hollidaysburg, 26° Smethport, 26°; Selins Grove, 26°, and Somerset, 26°.

From January 1, 1894, to October 31, 1894, the accumulated excess in daily mean temperature at Philadelphia was 521°; at Erie, 762°, and at Pittsburg, 673°.

For the same period the deficiency in precipitation at Philadelphia was 1·57; Erie, 4·17, and Pittsburgh, 8·83.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
October, 1888,	46°·1	4·03
1889,	47°·3	3·85
1890,	50°·9	5·87
1891,	50°·4	3·06
1892,	50°·5	0·78
1893,	52°·8	3·26
1894,	53°·6	4·26

The means of the daily maximum and minimum temperatures, 63°·4 and 43°·8, respectively, give a monthly mean of 53°·6, which is 0°·8 above the corresponding month of 1893.

The average daily range was 19°·6.

Highest monthly mean, 57°·6 at Philadelphia [Centennial Avenue].

Lowest monthly mean, 48°·3 at Wellsboro.

Highest temperature recorded during the month, 88° on the 1st at Lock Haven.

Lowest temperature, 24° on the 18th and 19th at Shingle House, and on the 15th at Wellsboro.

Greatest local monthly range, 58° at Somerset.

Least local monthly range, 37° at Easton.

Greatest daily range, 56° at Shingle House.

PRECIPITATION.

The average precipitation for the State, for the month, 4·26 inches, is 0·78 inches more than the average [3·48] for the last six years.

General rains occurred on the 4th, 5th, 10th, 13th, 24th, 25th, and 31st.

Excessive rains occurred at 11 stations on the 10th. Cassandria reported 3·0 inches of snowfall, and Grampian 1·0 inch. Several stations reported a trace.

The largest monthly totals of rainfall were: Girardville, 7·66; Seisholtzville, 7·48; Mauch Chunk, 7·06; South Eaton, 6·50; Blooming Grove, 6·42, and Reading, 6·40.

The least were: Greenville, 0·65; Lock No. 4, 1·36; Beaver Dam, 1·65; Pittsburg, 1·72; Altoona, 1·77, and West Newton, 1·82.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 9; clear days, 12; fair days, 8; cloudy days, 11.

BAROMETER.

The mean pressure for the month, 30·00, is about ·07 below the normal. At the United States Weather Bureau Stations, the highest observed was 30·38 at Harrisburg on the 12th, and the lowest 29·13 at Philadelphia on the 10th.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Hollidaysburg, 13th; Cassandria, 13th; Johnstown, 13th; Emporium, 13th, 24th; Mauch Chunk, 4th; State College, 24th; West Chester, 4th; Coatesville, 31st; Kennett Square, 31st; Lock Haven, 4th, 24th; Carlisle, 3d, 4th, 13th; Harrisburg, 3d; Uniontown, 22d; Easton, 3d; Blooming Grove, 3d; Shingle House, 23d; Somerset, 24th; Dyberry, 3d; Hamlinton, 3d; York, 24th; Lebanon, 3d; Phœnixville, 31st; Lewisburg, 3d, 4th, 13th.

Hail.—Cassandria, 13th; Johnstown, 14th; Emporium, 13th; Grampian, 13th; Lock Haven, 13th; Coopersburg, 14th; Greenville, 13th; Logania, 13th; Shingle House, 13th, 31st; Wellsboro, 13th; York, 13th, 14th.

Snow.—Hollidaysburg, 14th; Le Roy, 14th; Towanda, 14th; Cassandria, 14th; Johnstown, 14th; Emporium, 14th; Grampian, 14th; Saegerstown, 14th, 15th; Smethport, 14th; Blooming Grove, 14th; Shingle House, 14th; Dyberry, 14th.

Frost.—Pittsburg, 7th, 9th, 12th, 15th; Hollidaysburg, 7th, 12th, 15th, 16th, 18th, 19th; Le Roy, 14th, 15th; Towanda, 2d, 7th, 15th, 16th, 18th, 19th; Quakertown, 7th, 12th, 16th, 19th; Cassandria, 2d, 6th, 7th, 8th, 12th, 15th, 18th, 19th, 28th; Johnstown, 7th, 11th, 15th, 16th, 18th, 19th; Emporium, 12th, 18th, 19th, 29th; Mauch Chunk, 12th, 19th; State College, 6th, 12th, 15th, 19th; West Chester, 12th, 15th; Coatesville, 7th, 12th, 14th, 15th, 16th, 19th; Kennett Square, 7th, 12th, 15th, 16th; Westtown, 12th, 15th, 16th, 19th; Grampian, 7th, 19th; Lock Haven, 1st, 2d, 6th, 7th, 8th, 9th, 10th, 12th, 13th, 14th, 15th, 16th, 17th, 18th, 19th; Saegerstown, 15th, 16th; Carlisle, 12th, 15th; Harrisburg, 2d, 7th, 12th, 15th, 16th, 18th, 19th, 28th; Edinboro, 7th, 18th; Uniontown, 7th, 9th, 11th, 18th, 19th, 26th; Huntingdon, 12th, 15th, 16th, 18th; Coopersburg, 7th, 19th, 28th; Wilkes-Barre, 29th; Greenville, 7th, 15th, 18th, 26th; Pottstown, 12th, 16th; Easton, 7th, 15th, 16th; *Philadelphia* [Weather Bureau], 12th, 15th, 16th; [Centennial Avenue], 12th, 15th; Shingle House, 18th; Selins Grove, 2d, 6th, 7th, 8th, 9th, 10th, 14th; Somerset, 6th, 11th, 14th, 15th, 16th, 17th, 18th, 24th, 26th; Wellsboro, 2d, 7th, 12th, 14th, 15th, 29th; Dyberry, 2d, 7th, 8th, 9th, 12th, 16th, 18th, 19th, 28th; Honesdale, 3d, 6th; Hamlinton, 15th, 18th, 19th, 28th; South Eaton, 7th, 12th, 15th, 16th, 19th, 28th; York, 2d, 7th, 12th, 19th, 28th; Lancaster, 6th, 7th, 12th, 15th, 28th; Lebanon, 12th, 15th, 16th, 18th; Phoenixville, 7th, 15th, 16th; Lewisburg, 11th, 12th, 14th.

Sleet.—Wellsboro, 13th.

Coronæ.—Saegerstown, 9th; Lebanon, 18th.

Solar Halo.—*Philadelphia* [Centennial Avenue], 19th.

Meteors.—Emporium, 28th.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR OCTOBER, 1894

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR OCTOBER, 1894.

COUNTY.	STATION	Elevation above Sea Level (feet).	TEMPERATURE.									PRECIPITATION.				NUMBER OF DAYS.			Wind.	OBSERVERS
			Mean.	MAXIMUM.		MINIMUM.		Mean of Maximum.	Mean of Minimum.	DAILY RANGE.		Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.	Prevailing Direction.	
				Highest.	Date.	Lowest.	Date.			Mean.	Greatest.									
Allegheny,	Pittsburgh,	820	56·0	82	19	34	15	66·2	46·5	19·7	38	1·72	...	...	10	10	15	6	NW	O. D. Stewart, W. B.
Berks,	Hamburg.	380	55·0	77	2	31	16	64·4	45·7	18·7	36	6·36	...	...	5	9	12	10	W	William Shipe.
Berks,	Reading,[2]	280	53·8	...	...	...	...	...	...	...	...	6·40	...	...	11	...	...	...	...	Franklin Yager.
Blair,	Altoona,	1,181	57·4	79	1	37	15	65·4	49·4	16·0	27	1·77	...	...	7	...	...	...	...	Dr. C. B. Dudley.
Blair,	Hollidaysburg (30 days),	947	52·5	82	20	20	12	65·8	39·2	26·6	49	2·36	T	...	9	15	1	14	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	51·0	74	20	29	15	59·1	43·0	16·1	35	5·29	T	...	12	13	2	16	SW	G. W. T. Warburton.
Bradford,	Towanda,		51·6	76	3, 21	29	16	61·4	41·9	19·5	35	5·97	T	...	9	12	4	15	W	Hiram E. Bull.
Bucks,	Forks of Neshaminy[1],	304	56·3	...	...	...	...	...	...	...		5·38	...	...	9	11	11	9	NW	J. C. Hilsman.
Bucks,	Quakertown,	536	53·1	78	3	29	16	63·3	42·9	20·4	38	5·80		...	6	9	13	9	SW	J. L. Heacock.
Cambria,	Cassandria	2,100	51·3	73	3	31	15	58·6	44·0	14·6	35	2·81	3·0	...	9	6	13	12	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	54·4	82	19	29	15	65·5	43·4	22·1	48	2·44	T	...	14	10	11	10	S	E. C. Lorentz.
Cameron,	Emporium,	1,050	52·4	79	3	29	18	63·1	41·6	21·5	47	3·94	T	...	10	10	8	13	E	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	52·3	75	2	30	12, 16	62·2	42·4	19·8	38	7·06	T	...	8	15	5	11	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	52·0	77	20	32	15	61·1	43·0	18·1	33	3·14	...	...	10	8	10	13	W	Prof. Wm. Frear.
Chester,	West Chester,	455	55·6	79	3	33	15	63·6	47·4	16·2	26	5·89	...	...	9	18	1	12	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	55·5	83	3	29	16	66·2	44·8	21·4	38	5·57	...	...	7	10	7	8	S	W. T. Gordon.
Chester	Kennett Square,	275	55·2	81	3	31	16	65·0	45·3	19·7	35	5·48	...	...	10	15	1	15	SW	B. P. Kirk.
Chester,	Phœnixville,	190	55·5	79	3	33	16	64·3	46·7	17·6	34	6·17	...	...	12	11	5	15	NW	Knowles Croskey.
Chester,	Westtown (30 days),	350	53·8	80	3	32	16	61·9	45·8	10·1	30	5·58	...	...	9	11	8	11	W	John D. Carter.
Clearfield,	Grampian,	1,450	51·4	76	20	30	15	60·4	42·5	17·9	42	2·97	1·0	...	9	8	12	11	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	53·4	88	1	...	...	...	...	...	...	5·73	...	...	10	9	3	19	W	Prof. J. A. Robb.
Columbia,	Bloomsburg— State Normal School,	500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. J. G. Cope.
Crawford,	Saegerstown,	1,200	51·0	80	21	25	18	63·6	38·4	25·2	48	2·31	T	...	11	9	6	16	SE	J. G. Apple.
Cumberland,	Carlisle (29 days),	480	54·5	83	3	31	16	65·6	43·4	22·2	40	4·58	...	...	4	14	8	7	W	J. E. Pague.
Dauphin,	Harrisburg,	480	55·0	81	3	36	16	63·0	48·0	15·0	29	4·00	...	...	9	10	11	10	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	361	56·0	80	3	34	16	63·2	48·9	14·3	30	4·74	...	...	6	10	14	7	W	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	50·8	73	21	28	16	...	...	...	...	...	T	...	...	...	...	...	S	C. F. Sweet.
Erie,	Erie,	1,400	55·0	81	21	35	14	63·0	47·0	16·0	31	5·35	...	...	15	6	14	11	S	P. Wood, W. B.
Fayette,	Uniontown,	681	56·0	80	2	30	15	66·9	45·2	21·7	38	2·41	...	...	7	17	7	7	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	54·2	84	3	30	16	65·5	42·8	22·7	39	5·44	...	...	8	12	10	9	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	54·0	81	3, 20	27	18	66·8	41·2	25·6	44	2·93	...	...	9	16	5	10	W	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	55·1	82	3	30	16	65·4	44·8	20·6	34	5·36	...	...	7	13	12	6	SW	A. V. Heister
Lebanon,	Lebanon,	458	54·4	81	3	30	16	64·7	44·0	20·7	36	6·14	...	...	9	15	6	10	NE	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	54·3	76	3	35	15	61·5	47·1	14·4	27	5·62	...	...	11	14	10	7	SE	Dr. M. H. Boye.
Luzerne,	Drifton (27 days),	1,683	52·0	77	2	35	15	60·4	43·6	16·8	32	5·15	...	...	8	11	5	11	NW	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	51·1	80	1, 29	31	15, 16, 19	65·0	43·2	21·8	42	5·53	...	...	4	8	13	10	W	A. W. Betterly.
McKean,	Kane,	2,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. H. Kemp.
McKean,	Smethport,	1,500	50·0	78	19, 20, 21	26	18	60·8	39·1	21·7	51	3·37	T	...	9	9	8	14	W	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	49·7	81	21	28	15	61·0	38·4	22·6	42	0·65	...	...	5	14	4	13	...	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	56·0	80	3	33	16	65·3	46·8	18·5	36	5·20	...	...	6	13	10	8	NW	Charles Moore, D.D.S.
Northampton,	South Bethlehem,		55·6	78	3	37	16	62·0	49·2	12·8	27	...	...	...	...	...	...	...	...	T. Merriman.
Northampton,	Easton— Lafayette College,	325	53·8	72	3, 4	35	15, 16	61·6	46·0	15·6	28	5·47	...	...	9	16	3	12	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	55·3	79	3	32	12, 16	65·1	43·4	19·8	36	5·56	...	...	8	13	6	12	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	57·0	82	3	37	15	64·5	50·0	14·5	25	4·60	...	...	10	11	8	12	NE	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	57·6	81	3	37	15	65·6	49·6	16·0	27	5·62	...	...	9	12	10	9	NE	John Comly.
Pike,	Blooming Grove,*[1]	...	49·8	78	20	31	28	...	...	...	...	6·42	T	...	11	4	16	11	NW	John Grathwohl.
Potter,	Shingle House,	1,475	50·4	83	19, 21	24	18, 19	62·4	38·4	24·0	56	3·33	T	...	13	12	5	14	W	C. D. Voorhees, M.D.
Snyder,	Selins Grove,	455	53·8	80	5	26	9	69·2	38·3	30·9	44	5·58	...	...	7	19	4	8	SW	J. M. Boyer,
Somerset,	Somerset,	2,250	51·4	84	2	26	15	65·5	37·2	28·3	43	3·20	...	...	5	8	17	6	SE	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	48·3	78	20	24	15	...	...	...	...	3·81	...	...	10	9	5	17	S	H. D. Deming
Union,	Lewisburg (29 days),	450	53·1	75	2	32	18, 19, 20	65·2	41·0	24·2	42	0·02	...	...	7	8	4	17	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	49·2	79	20	25	16	60·1	38·2	21·9	44	5·41	T	...	8	14	4	13	NW	Theodore Day.
Wayne,	Honesdale,	1,000	51·1	73	2	31	16	59·8	42·4	17·4	37	5·64	...	...	13	15	5	11	W	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	51·0	80	20	30	15	59·4	42·7	16·7	36	5·18	...	...	13	9	8	14	W	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	55·4	78	1, 22	29	15	63·8	46·9	16·9	31	2·58	...	...	6	...	...	...	...	Murray Forbes
Westmoreland,	Ligonier,	1,750	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. D. Ambrose.
Wyoming,	South Eaton,	660	52·0	76	21	31	16	61·4	42·5	18·9	38	0·50	...	...	8	13	8	10	NW	B. M. Hall.
York,	York,	385	54·7	83	3	30	16	65·0	44·4	20·6	38	4·24	T	...	8	13	13	5	W	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 8.

3	4	5	6
. .	. .	. .	. .
. .	·11	·27	·14
. .	·33	·04	·03
. .	·08	·05	·13
. .	·11	. .	·12
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. .	·04	. .	·07
. .	·10	·03	·08
. .	·50	. .	·05
. .	. .	. .	·22
·40	. .	. .	. .
·33	·05	·06	. .
. .	. .	. .	. .
. .	. .	. .	. .
. .	·12	. .	·07
. .	·07	·05	·05
. .	·05	·02	·10
. .	·11	·12	·21
·03	. .	·05	. .
. .	·16	·09	·18
. .	·06	·12	·40
. .	·16	·06	·07
·14	·08	·05	·17
·12	. .	·30	·10
·15	. .	. .	. .
. .	·36	. .	. .
·47	. .	·08	. .
. .	. .	·15	·16
. .	·17	·02	·06
·62	·03	·02	. .
·24	·19	2·15	·35

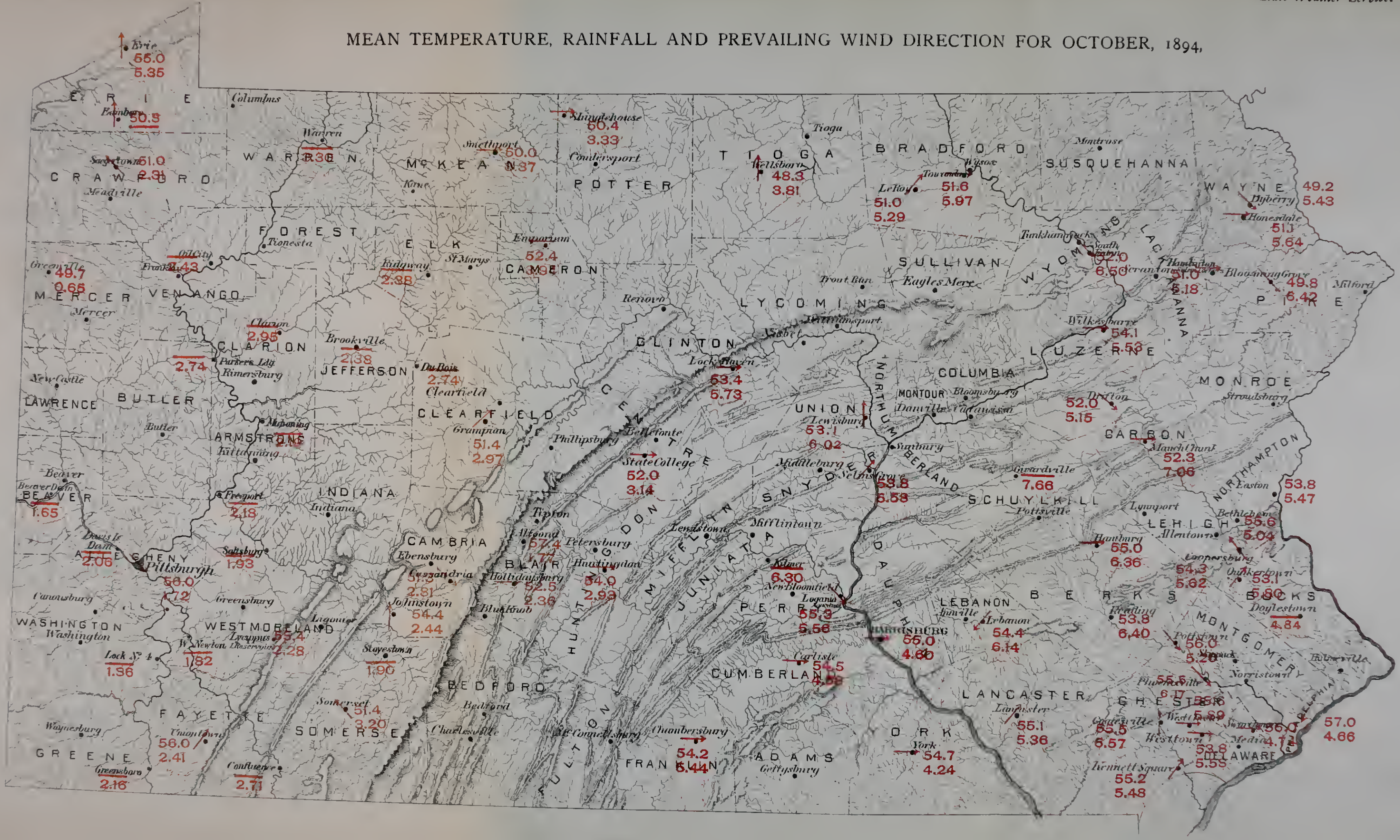
PRECIPITATION DURING OCTOBER, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Bethlehem,			·61							2·11			·26										·88		·47						·71	5·04
Blooming Grove,				·87					·70	2·27			·46												‖·48	·52					§1·12	6·42
Browers Lock,				·72	·05					2·99			·26											·20	·49				·08		·81	5·60
Coatesville,			·05	·42						3·19			·42											·43	·16						·90	5·57
Coopersburg,				·57	·01					2·44			·59	·01								·01		·75	·41	·01				·03	·79	5·62
Doylestown,				·59	·19				1·85				·39											·27	·51						1·04	4·84
Dyberry,				·95	·11				·14	2·26			·38											·42	·11						1·06	5·43
Easton,					·75					2·28			·33	·02								·01				1·25			·01	·03	·79	5·47
Forks of Neshaminy,				·30	·13					1·96			·44											·12	·96				·12	·05	1·30	5·38
Frederick,				·26	·15					2·28			·38											·74	·41						·77	4·99
Hamburg,			·74							2·45			·53										1·82								·82	6·36
Honesdale,	·04			·98	·03	·02			·12	2·35			·41	·02	·02							·03		·42	·11						1·09	5·64
Kennett Square,				·45	·05					2·45			·45										·44	·44				·10	·02	·98	·10	5·48
Lansdale,				·19	·49						2·61		·41											·31	·33	·21					1·00	5·55
Mauch Chunk,				·96	·03					3·46			·62	·05										·39	·20						1·35	7·06
Ottsville,				·41	·06					1·61			·47									·01		1·00	·38	·03					·98	4·95
Philadelphia, a†				·21	·01					1·76			55											·23	·58			·01	·07	·03	1·21	4·66
Philadelphia, b,				·44	·01					2·33			·39											·34	·75				·13	·01	1·22	5·62
Phœnixville,			·60	·01	·06					3·41			·36	·03						·01				·70	·04				·10	·40	·45	6·17
Point Pleasant,			·16	·21							1·66		·50											·45	·69					·03	1·05	4·75
Pottstown,			·57	·12						2·55			·40											·75							·81	5·20
Quakertown,				·61	·06					2·41			·50												1·38						·84	5·80
Reading,				·60	·02					3·57			·24	·02								·01		·80	·56				·01	·01	·56	6·40
(Salem Corners) Hamlinton,				·90	·06	·04			·03	2·02	·03		·34	·14	·02									·37	·23	·02					1·00	5·18
Seisholtzville,				·59						2·85			·39											2·30	·49						·86	7·48
Smith's Corner,				·38	·07					1·76			·56											·49	·88					·04	1·05	5·23
Swarthmore,			·32							2·23			·31												·65						‡1·23	4·74
West Chester,				·53	·22					2·48			·40											·62	·55				·13	·02	·94	5·89
Westtown,			·01	·40	·10					2·60			·35				*								·85				·13	·04	1·10	5·58
Susquehanna Basin.																																
Altoona,				·16					·07	·48			·18	·06										·12							·70	1·77
(Aqueduct) Logania,			·40	·03						2·15			·65	·02										·87	·05						1·39	5·56
Bloomsburg,																																
Carlisle,									2·35				1·01												·71					*	·51	4·58
Drifton,			·36		·10		*		·80	2·44			·34	*							*			·05				*		·12	·94	5·15
Emporium,			·27	·07	·05			·15		·47			·73			·07								1·35			·03				·75	3·94
Gettysburg,																																
Girardville,			1·18	·26					2·92				·80											·80	·15						1·55	7·66
Grampian,			·23	·04	·05			·08		·38			·75	·21										·48							·75	2·97
Harrisburg,†			·37	·46	·02					1·50			·25	·04										·92	·02						1·02	4·60
Hollidaysburg,		*	·26		·04			·05		·67			·35	·06										·19						·03	·71	2·36
Huntingdon,	·03		·40		·01					·85			·33	·06										·35	·01						·89	2·93
Kilmer,			1·05					·10		1·40			·75	·01										·86							2·13	6·30
Lancaster,			·80	·04					2·30				·15											·91	·21						·95	5·36
Lebanon,			·24	·36						2·85			·36									·02		1·12	·10				·05		·94	6·14
Le Roy,	·04		·06	·08	·29				·22	1·80			·19			·03								1·24	·24	·01					1·09	5·29
Lewisburg,			·74	·14					·08	1·57			·37											1·71	*			*			1·41	6·02
Lock Haven,	·42		·30	·02	·01			·06		1·67			·48											1·66	·06						1·05	5·73
Selins Grove,			1·64	·41				·03	1·03				·47											·75							1·25	5·58
South Eaton,			·84		·10				·34	2·30			·28											·98	·44						1·22	6·50
State College,			·27	·02					·09	1·04			·41			·01								·47	·02			·02			·79	3·14
Towanda,	·09		·51	·20				·28		2·16			·04			·03								1·71							·95	5·97
Wellsboro,			·20	·04		·05		·15		1·20			·20	·10									·02	·30							1·55	3·81
Wilkes-Barre,										4·02			·47										·43								·61	5·53
York,				·33						2·01			·24								·01			·80	·02				·02		·81	4·24

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		Total.
Ohio Basin.																																
Beaver Dam,											·03		·19	·10		·05							·28	·25							·75	1·65
Brookville,				·11	·27	·14							·10	·16	·07									·72							·81	2·38
Cassandria,				·33	·04	·03			·14		·59			·34	·30									·22							·82	2·81
Clarion,				·08	·05	·13	·03				·09		·22	·20	·35								·17	·65							·98	2·95
Confluence,	·28			·11		·12			·01	·55	·04		·25	·20	·03									·13							·59	2·31
Davis Island Dam,				·04		·12					·01		·14	·15		·06							·32	·20							1·02	2·06
DuBois,				·20	·07	·10			·02	·14	·18		·28		·11	·01								·81	·05						·77	2·74
Elwood Junction,				·04		·07						·04	·22	·16	·11	·08							·24	·21							·32	1·49
Freeport,	·27			·10	·03	·08					·05		·19	·13		·09							·22	·20							[illegible]	2·15
Greensboro,				·50		·05				·25			·30	·25									·17	·01							·63	2·16
Greenville,						·22						·08	·28											·03						·04		[illegible]
(Immel Reservoir) Lycippus,			·40							·40			·28										·15	·25							·80	[illegible]
Johnstown,	·01		·33	·05	·06			·02	·47	·05		·34	·10	·05		·01								·28						·56	[illegible]	2·44
Kane,																																
Ligonier,																																
Lock No. 4,	·08			·12		·07				·03			·17			·05							·05	·25							·54	1·36
Mahoning,				·07	·05	·05							·29	·47	·06	·06							·14	·14							·80	[illegible]
Oil City,				·05	·02	·10			·01		·08		·24	·24	·26	·08							·14	·36							[illegible]	2·43
Parker's Landing,	·13			·11	·12	·21					·05		·35	·20	·17	·03							·13	·30	·01						·93	2·74
Pittsburg,†			·03		·05								·22	·02		·02						·44	·02	·25						·05	·02	[illegible]
Ridgway,	·11			·16	·09	·18			·12	·06			·24	·04	·24								·09	·56							[illegible]	[illegible]
Saegerstown,				·06	·12	·40		·04		·03	·30		·25	·15	·10	·16															·70	2·31
Saltsburg,	·02			·16	·06	·07				·11			·20	·25		·05								·19							·32	1·43
Shingle House,			·14	·08	·05	·17		·15		·33	·14		·30	·02		·07							·10	1·31							·47	3·33
Smethport,			·12		·30	·10				·20						·10							·05	1·20							·65	[illegible]
Somerset,			·15						·95			·35											·80							·95		3·20
Stoyestown,				·36			·29		·18	·13	·03			·06	·26	·21								·38								1·90
Uniontown,			·47		·08					·38			·37										·14							·45	·49	2·41
Warren,					·15	·16			·06		·45	·02	·31	·20	·01	·05								1·15	·03						·71	3·30
West Newton,				·17	·02	·06				·07	·03		·30	·15		·03							·02	·33							·64	[illegible]
Potomac Basin.																																
Chambersburg,			·62	·03	·02					1·58			·33										·02	1·40							·44	4·44
Lake Basin.																																
Erie,†			·24	·19	2·15	·35		·04		·02	·14	·04	·26	·30							·16		·03	·62						·05	[illegible]	5·35

† U. S. Weather Bureau Stations. * Missing. § Total rainfall for 30th and 31st. ‖ Total rainfall from 22d to 25th, inclusive. ‡ Total rainfall from 29th to 31st, inclusive.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR OCTOBER, 1894,



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. Townsend, Weather Bureau, Observer in Charge.

MONTHLY WEATHER REVIEW.

For November, 1894.

Hall of the Franklin Institute,
Philadelphia, November 30, 1894.

GENERAL REVIEW.

The average temperature for November, 1894, 38°·2, is 2°·0 below the average [40°·2] for the past seven years.

The highest recorded temperatures occurred on the 2d and 3d, and were as follows: Pittsburgh, 74°; Johnstown, 72°; Lock Haven, 72°, and Selins Grove, 72°.

The lowest were on the 20th, 26th and 29th. Saegerstown, 6°; Shingle House, 8°; Wellsboro, 8°; Somerset, 10°; Dyberry, 10°, and Salem Corners, 10°.

From January 1, 1894, to November 30, 1894, the accumulated excess in daily mean temperature at Philadelphia was 427°; at Erie, 656°, and at Pittsburgh, 553°.

For the same period the deficiency in precipitation, in inches, at Philadelphia, was 1·56; Erie, 6·70, and Pittsburgh, 9·64

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
November, 1887, ...	39°·2	1·80
1888, ...	42°·0	3·37
1889, ...	41°·0	6·72
1890, ...	41°·5	1·49
1891, ...	39°·6	2·65
1892, ...	39°·1	4·34
1893, ...	39°·1	2·93
1894, ...	38°·2	2·50

The means of the daily maximum and minimum temperatures, 46°·2 and 30°·2, respectively, give a monthly mean of 38°·2, which is 0°·9 below the corresponding month of 1893.

The average daily range was 16°·0.

Highest monthly mean, 45°·1 at Altoona.

Lowest monthly mean, 32°·0 at Wellsboro.

Highest temperature recorded during the month, 74° on the 2d at Pittsburgh.

Lowest temperature, 6° on the 26th at Saegerstown.

Greatest local monthly range, 63° at Saegerstown.

Least local monthly range, 39° at Altoona.

Greatest daily range, 48° at Drifton.

PRECIPITATION.

The average precipitation for the State, for the month, 2·50 inches, is 0·83 inches less than the average [3·33] for the last seven years.

General rains occurred on the 3d, 5th, 8th, 9th, 10th, 17th, 23d, and 30th.

The snowfall was generally light. The greatest totals in inches were Edinboro, 26·0; Cassandria, 20·0; Shingle House, 16·5; Grampian, 14·0, and Smethport, 11·0.

Very little remained on the ground at the end of the month.

The largest monthly totals of rainfall were: Warren, 3·64; Quakertown, 3·52; Mauch Chunk, 3·33; Philadelphia [Centennial Avenue], 3·33; Forks of Neshaminy, 3·28, and *Philadelphia* [Weather Bureau], 3·26.

The least were: Altoona, 0·74; Chambersburg, 1·28; Brookville, 1·39; Hollidaysburg, 1·40; State College, 1·59, and Ridgway, 1·65.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 9; clear days, 10; fair days, 9; cloudy days, 11.

BAROMETER.

The mean pressure for the month, 30·12, is about ·07 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·76 at Harrisburg on the 29th, and the lowest 29·62 at Erie on the 3d.

MISCELLANEOUS PHENOMENA.

Hail.—Quakertown, 9th, 10th; Phœnixville, 30th.

Snow.—Hollidaysburg, 7th, 10th, 13th, 19th, 25th; Le Roy, 5th, 6th, 7th, 8th, 10th, 11th, 12th, 13th, 14th, 15th, 19th, 24th, 25th, 28th, 30th; Towanda, 5th, 6th, 7th, 8th, 11th, 19th, 24th, 25th, 28th, 29th, 30th; Quakertown, 7th, 8th, 9th, 10th, 24th, 30th; Cassandria, 5th, 6th, 7th, 10th, 11th, 13th, 14th, 19th, 24th, 25th, 28th; Johnstown, 5th, 8th, 10th, 11th, 25th, 26th, 28th; Emporium, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 19th, 24th, 25th, 28th, 30th; E. Mauch Chunk, 8th, 10th, 30th; State College, 5th, 7th, 24th; Coatesville, 9th; Phœnixville, 9th, 30th; Westtown, 9th; Lock Haven, 12th, 25th, 30th; Saegerstown, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 15th, 17th, 18th, 28th, 30th; Carlisle, 11th, 13th; Uniontown, 6th, 10th; Lebanon, 7th, 13th, 19th, 24th, 30th; Coopersburg, 8th 10th, 24th, 28th, 30th; Drifton, 8th, 11th, 30th; Wilkes-Barre, 8th, 23d, 30th; Smethport, 8th, 11th, 24th, 25th, 28th, 30th; Logania, 13th, 19th, 24th, 30th; Philadelphia [Centennial Avenue], 9th, 24th, 30th; Blooming Grove, 5th, 8th; Shingle House, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 19th, 24th, 25th, 26th, 27th, 28th, 29th, 30th; Selins Grove, 8th, 16th, 30th: Somerset, 7th, 9th, 10th, 25th; Wellsboro, 7th, 8th, 9th, 13th, 30th; Lewisburg, 8th; Dyberry, 5th, 8th, 10th, 13th, 19th, 24th, 28th, 30th; Honesdale, 8th, 10th, 24th, 30th; South Eaton, 8th, 30th; York, 7th, 10th, 11th, 30th; Hamlinton, 5th, 8th, 9th, 10th, 13th, 18th, 19th, 28th, 30th; Greenville, 10th, 11th.

Sleet.—Cassandria, 30th; Johnstown, 30th; State College, 30th; Phœnixville, 30th; Lock Haven, 7th, 9th; Philadelphia [Centennial Avenue], 11th, 24th; Somerset, 30th; Wellsboro, 7th, 8th; York, 30th.

Aurora.—Lock Haven, 12th.

Coronæ.—Cassandria, 2d.

Solar Halo—Le Roy, 29th.

Lunar Halo.—Carlisle, 11th.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR NOVEMBER, 1894.

COUNTY.	STATION.	Elevation above Sea Level (feet).	TEMPERATURE.										PRECIPITATION.				NUMBER OF DAYS.			Wind.	OBSERVERS
				MAXIMUM.		MINIMUM.				DAILY RANGE.									Prevailing Direction.	
			Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.	Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.		
Allegheny,	Pittsburgh,	820	40·4	74	2	22	20, 29	48·0	32·0	16·0	30	1·80	0·3	. . .	15	7	9	14	NW	O. D. Stewart, W. B.
Berks,	Hamburg.	380	39·0	68	2	16	20	46·4	31·6	14·8	35	3·06	. . .	.	7	7	13	10	NW	William Snipe.
Berks,	Reading,[2]	280	38·2	. . .		. . .	. . .	. . .		.	. . .	2·49	. . .	. . .	9	. .	. .	.	. . .	Franklin Yager.
Blair,	Altoona,	1,181	45·1	65	3	26	29	52·8	37·4	15·4	29	0·74	. . .	. . .	7		. .	. .	. . .	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	37·9	69	2	13	20, 29	48·5	27·3	21·2	39	1·40	. . .		11	12	3	15	W	Prof. J. A. Stewart.
Bradford.	Le Roy,	1,400	32·6	64	2	12	29	39·0	20·3	12·7	27	2·47	4·2	0·8	12	8	5	17	SW	G. W. T. Warburton.
Bradford,	Towanda,		36·0	69	2	15	20	[illegible]	[illegible]	13·7	38	1·94	4·5	1·0	7	10	14	6	W	Hiram E. Bull.
Bucks,	Forks of Neshaminy (29 days),[1]	304	43·4		. . .	. . .						3·28	. .	. .	12	13	10	6	W	J. C. Hilsman.
Bucks,	Quakertown (24 days).	536	36·0	68	2	16	20	46·2	29·9	16·3	35	3·52	. . .	.	8	4	14	6	NW	J. L. Heacock.
Cambria,	Cassandria	2,100	35·2	60	2	13	20	40·2	30·2	10·0	27	3·18	20·0	.	12	7	9	14	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	38·6	72	2	12	20	47·7	29·6	18·1	38	2·55	4·5		16	12	4	14	S	E. C. Lorentz.
Cameron,	Emporium,	1,050	36·4	66	2	16	20	44·1	28·6	15·5	35	1·81	7·5	1·3	10	9	6	15	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	37·0	65	2	13	20	45·4	28·6	16·8	35	3·33	5·8	2·0	7	13	8	[illegible]	N	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	36·5	65	2	16	20, 28	44·1	28·8	15·3	29	1·59	3·0	0·8	7	9	9	12	W	Prof. Wm. Frear.
Chester,	West Chester,	455	40·2	66	2	20	20, 29	47·7	32·7	15·0	24	2·78	. .	. . .	11	18	3	9	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	39·4	70	2	17	20	49·6	29·1	20·5	34	2·73	. .	.	8	15	8	7	W	W. T. Gordon.
Chester	Kennett Square,	275	40·3	70	2	18	20	49·4	31·2	18·2	30	2·88	. . .	.	11	16	3	11	W	B. P. Kirk.
Chester,	Phœnixville,	190	39·8	67	2	20	29	47·6	32·1	15·5	28	3·17	T	T	14	12	6	12	NW	Knowles Croskey.
Chester,	Westtown (28 days),	350	39·6	67	2	18	20	46·6	32·5	14·1	29	2·85	T		10	13	3	12	W	John D. Carter.
Clearfield,	Grampian,	1,450	33·8	61	2	12	20	39·8	27·8	12·0	28	3·04	14·0	2·0	11	7	9	14	W	Nathan Moore.
Clinton,	Lock Haven,[1]	560	39·0	72	2	16	20	47·7	30·4	17·3	40	1·99	2·5	1·0	10	10	2	18	W	Prof. J. A. Robb.
Columbia,	Bloomsburg— State Normal School,	500	. . .		. . .			. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	.	. . .	.	. . .	Prof. J. G. Cope.
Crawford,	Saegerstown,	1,200	34·8	69	2	6	26	43·7	26·0	17·7	40	2·61	11·0	.	14	. .	12	18	S	J. G. Apple.
Cumberland,	Carlisle,	480	39·9	70	1	19	20, 28	47·2	32·6	14·6	33	2·63	1·0	. .	6	12	11	7	W	J. E. Pague.
Dauphin,	Harrisburg,	480	40·0	67	2	23	20	46·0	34·0	12·0	26	1·90	T	. . .	7	10	10	10	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	361	41·0	64	2	22	20, 30	46·6	35·3	11·3	22	2·82		. .	. . .	11	12	7	NW	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	33·8	62	2	16	20	. . .	. . .	. .	. . .	. . .	26·	2·0	. . .	5	8	17	SW	C. F. Sweet.
Erie,	Erie,	1,400	39·0	71	2	22	20	46·0	31·0	15·0	33	1·00		. .	17	2	14	14	S	P. Wood, W. B.
Fayette,	Uniontown,	681	41·4	66	2	21	20, 29	[illegible]	33·6	15·7	36	2·96	.	. . .	8	10	8	12	NW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	39·3	68	2	18	20, 29	48·6	30·0	18·6	39	1·28		. . .	6	6	13	11	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	39·0	70	2	14	20	48·6	29·4	19·2	40	1·81	. . .	. . .	9	11	5	14	W	Prof. W. J. Swigart.
Lancaster,	Lancaster (27 days)— Franklin and Marshall Col'ge,	413	40·4	69	2	19	29	50·7	30·0	20·7	34	1·91		.	6	13	8	6	E	A. V. Heister
Lebanon,	Lebanon,	458	39·2	67	2	19	20, 29	47·7	30·6	17·1	32	2·57	1·0		7	12	9	9	SW	G. W. Hayes, C. E
Lehigh,	Coopersburg,	520	39·4	64	2	18	20	47·0	31·8	15·2	27	2·75	1·1	0·1	8	13	10	7	SW	Dr. M. H. Boye.
Luzerne,	Drifton (25 days).	1,683	38·2	68	3	13	19, 21	49·8	26·7	23·1	48	2·52	4·2	1·0	6	8	6	11	N	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	38·2	69	3	10	20	47·4	28·9	18·5	37	2·29	4·0	. . .	6	7	8	15	W	A. W. Betteriy.
McKean,	Kane,	2,000	. . .	. . .	. .		. .	. . .	. . .	. . .	. .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	C. H. Kemp.
McKean,	Smethport,	1,500	33·3	69	2	12	26	40·6	26·0	14·6	41	2·52	11·0	.	9	9	9	12	SW	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	35·8	68	2	13	12	43·5	28·0	15·5	33	2·47	3·0	. . .	13	6	8	16	. . .	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	41·0	69	2	20	20	48·2	33·8	14·4	30	2·80	. . .	. . .	8	15	10	5	NW	Charles Moore, D.D.S.
Northampton,	South Bethlehem,		39·0	64	2	19	20	44·6	33·3	11·3	24	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	T. Merriman.
Northampton,	Easton— Lafayette College.	325	38·5	62	2	18	20	45·4	31·6	13·8	30	2·70	. .	. .	8	9	14	7	. . .	J. W. Moore.
Perry,	(Aqueduct) Logania.	367	40·5	68	2	15	29	48·1	32·9	15·2	32	2·64	0·8	0·3	9	13	10	7	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau.	117	42·0	69	2	22	20	48·3	35·8	12·5	22	3·26	T	. . .	13	14	5	11	NW	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	42·5	69	2	23	20	49·4	35·6	13·8	24	3·33	T	. . .	12	13	5	12	NW	John Comly.
Pike,	Blooming Grove,*[1]	. . .	34·5	64	1	10	20		. . .	.	. . .	2·91	4·0	1·0	6	4	14	12	S	John Grathwohl.
Potter,	Shingle House,	1,475	33·8	69	2	8	29	41·8	25·8	16·0	45	2·42	10·5	T	19	6	5	19	W	C. D. Voorhees, M. D.
Snyder,	Selins Grove,	455	38·4	72	3, 4	16	29	48·4	28·5	19·9	35	2·08	3·0	2·0	5	. .	18	12	NW	I. M. Boyer,
Somerset,	Somerset,	2,250	34·2	66	4	10	26	44·1	24·2	19·9	36	[illegible]	7·0	.	10	2	17	11	NW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	32·0	64	2	8	20		.	. . .	. . .	3·06	8·0	1·5	10	7	7	16	S	H. D. Deming
Union,	Lewisburg (21 days).†	450	38·9†	68	2	18	20	48·0†	28·7	19·3	36	1·80	1·0	. .	7	5	11	14	W	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	33·4	68	2	10	20	41·6	25·2	16·4	41	2·21	7·0	2·0	8	9	7	14	NW	Theodore Day.
Wayne,	Honesdale,	1,000	36·6	62	2	16	20	41·3	29·8	13·5	29	2·18	9·0	.	7	13	9	8	W	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	34·4	68	2	10	20	41·3	27·6	13·7	31	[illegible]	7·9	. . .	12	3	14	13	W	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	37·0	70	3	16	29	45·1	29·0	16·1	32	2·45	. .	. .	7	. .	. .	. .	. . .	Murray Forbes
Westmoreland,	Ligonier,	1,750	. . .		. . .		. . .		. .	. . .	. .	. .	. . .	. . .	. . .	. .	.	. .	. . .	C. D. Ambrose
Wyoming,	South Eaton,	660	37·4	68	2	10	20	45·2	29·6	15·6	30	2·87	[illegible]	1·0	5	10	10	10	NW	R. M. Hall.
York,	York,	385	40·4	68	2	17	29	48·6	32·1	16·5	32	2·00	T	. . .	9	18	4	8	W	Mrs. L. H. Grenewald

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 2.

3	4	5	6	7
·25	. .	·14	·25	. .
·08	. .	·18	·06	. .
·35	. .	·28	·20	·30
·39	·08	·22	·15	·03
·42	. .	·42	·39	·09
·28	. .	·48	·10	·02
·51	. .	. .	. .	·22
·30	. .	·21	·22	. .
·46	·05	·24	·05	. .
·45	. .	·38	·25	·02
. .	·14	·01	·03	·15
·45	. .	·50	. .	. .
·36	. .	·48	·02	·30
. .	. .	. .	. .	. .
. .	. .	. .	. .	. .
·35	. .	·34	·13	·07
·32	. .	·26	·08	·03
·29	. .	·24	·24	·02
·35	·01	·55	·01	·03
·25	. .	·30	·05	·11
·50	. .	·25	·06	. .
·35	. .	·60	. .	. .
·40	. .	·36	·07	·01
·42	·02	·23	. .	·05
·55	. .	·22	. .	. .
. .	·30	·40	·12	·40
·79	. .	·51	·02	·18
·25	. .	·49	·15	·30
·58	·01	·45	·06	. .
·35	. .	·35	·17	. .
89	. .	·20	. .	·03
30	·02	·78	. .	·01

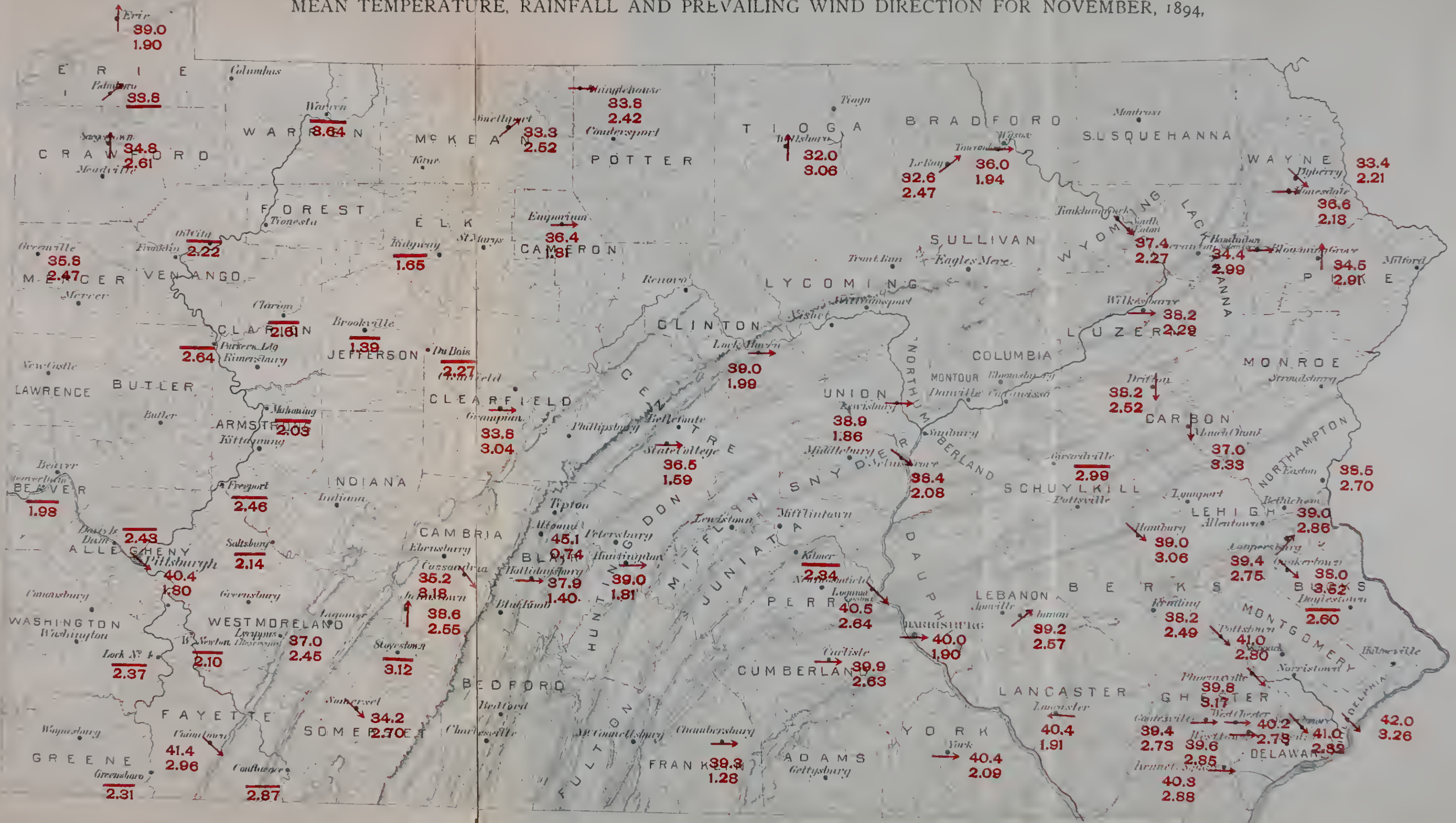
PRECIPITATION DURING NOVEMBER, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Bethlehem,			·93		·81			·43		·27							·32				·10											2·86
Blooming Grove,			1·24		·82			·39									·14						·20							·12		2·91
Browers Lock,	·10		·67		·84			·31	·04	·10				·04				·29			·15			·07						·14		2·73
Coatesville,			·92		·85			·22									·38		·01		·19		·06							·10		2·73
Coopersburg,			·98		·71			·38		·14							·30				·18		·05							·01		2·75
Doylestown,			·73		·79		·38							·08			·31				·21		·06							·04		2·60
Dyberry,			·67		·77			·42		·03							08						·05					·04		·15		2·21
Easton,			·40		1·20			·41		·23							·31				·13		·01							·01		2·70
Forks of Neshaminy,			·90		·80			·41	·05	·09				·06			·31	·05	·08		·34		·12							·07		3·28
Frederick,			·85		·80			·30		·11							·33				·18		·10							·02		2·64
Hamburg,			·96		·92			·34		·23							·25						·12							·24		3·06
Honesdale,			·87		·47			·50		·05							·05							·07						·17		2·18
Kennett Square,			·86		·75			·30	·06	·10				·04			24	·03			·28		·14							·08		2·88
Lansdale,			·95		·65		·37		·22								·38				·23		·31							·06		3·17
Mauch Chunk,			1·46		·95			·54		·05							·10						·07							·14		3·33
Ottsville,			·95		·89			·45	·02								·44				·15		·07							·14		3·14
Philadelphia, a†			1·29		·58			·29	·06	·10				·09			·24	·01	·01		·39		·06	·01						·13		3·26
Philadelphia, b,			1·14		·68			·31	·06	·11				·07			·27	·03	01		·41		·10							14		3·33
Phœnixville,			·90		·81			·29	·05	·10				·03	·01		·34	·02			·20	·02	·12	·03						·25		1·17
Point Pleasant,			·93		·85			·45							·06		·24				·21		·10							·04		2·88
Pottstown,			·70		1·00			·25	·11								·25				·18		·10							·15		2·80
Quakertown,			·84		·84			·45				*	*	*	*	·60	·46	·04			·23		·06									3·52
Reading,			·80		·70			·21		·31							·30				·03		·05	·01						·08		2·49
(Salem Corners)																																
Hamlinton,	·10		·89		·65	·09		·50	·10	·20		·05	·01				·10				·10									·20		2·99
Seisholtzville,			·98		·89			·33		·29							·25				·11		·05							·06		2·96
Smith's Corner,			·97		·84			·44		·10				·05			·24				·28		·10							·05		3·07
Swarthmore,																																2·82
West Chester,			·80		·69			·27	·06	·10				·05			·37	·02			·22		·08							·12		2·78
Westtown,			·85		·67			·30	·07	·07		*	*	·10			·28				·25		·11							·15		2·85
Susquehanna Basin.																																
Altoona,			·18		·20	·07		·18		·03															·05					·03		0·74
(Aqueduct) Logania,			1·31		·59			·10		·09			·01				·22					·05		·09						·15		2·64
Bloomsburg,																																
Carlisle,			1·15		·95				·05				·07										·10							·10		2·63
Drifton,			1·17		·61			·30			·02						·32													·10		2·52
Emporium,	·03		·53		·25			·40	·01	·16			·11	·02									·20							·10		1·81
Gettysburg,																																
Girardville,			1·40		·80			·24									·26						·11	·06						·12		2·99
Grampian,			·38		·62		·10	·50		·45	·08		·03				·08		·03				·12							65		3·04
Harrisburg,†			·95		·45			·02		·09							·30						·02							·07		1·90
Hollidaysburg,			·38		·28		·08	·22	·07	·05			·03				·04		·02				·09							·14		1·40
Huntingdon,	·52		·30		·42			·22		·07			·02				·04						·05							·07		1·81
Kilmer,			1·49		·43		·03	·12									·07						13							·07		2·34
Lancaster,		·86			*	*	*	·03									·46				·26		·03							·27		1·91
Lebanon,			·95		·81			·10									·38						·12	·03						·18		2·57
Le Roy,	·03		1·33		·49		·01	·27		·02	·01		·01				·15						·05					·05		·05		2·47
Lewisburg,			·85		·55			·23									11						·03						·06	·03		1·86
Lock Haven,	·02		·80		·30			·20	·02			·10					·11						·09		·05					·30		1·99
Selins Grove,			1·26		·54			·12									·10													·06		2·08
South Easton,			1·30		·47			·28								·12														·10		2·27
State College,			·66		·33			·22					·06				·01						·07							·24		1·59
Towanda,			·85		·55			·20									·13						·03		·08					·10		1·94
Wellsboro,			1·75		·20		·40	·23	·15	·02			·05			·05							·06							·15		3·06
Wilkes-Barre,			1·24		·56			·12									·11						·20							·06		2·29
York,			·78		·52			·03	·20	·05							·25				·01		·08							·17		2·09

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,			·25		·14	·25		·58		·14	·10		·05	·04			·04							·06						·33		1·98
Brookville,	·04		·08		·18	06		·12		·10	·02	·31	·04	07	·03		·12			01				·04	·05	·02			·06	·03		1·39
Cassandria,			·35		·28	·20	·30		·18	·65	·20						·13						·10		·50			·10		·19		3·18
Clarion,	·01		·39	·08	·22	·15	·03	·41	·02	·15	·14	·14	·11	·14	05		·09		·02	·03				·08	·08	·03			·04	·20		2·61
Confluence,	·11		·42		·42	·39	·09	·34	·06	·09	·01						·32	·14						·33						·15		2·87
Davis Island Dam,	·03		·28		·48	·10	·02	·40	·44	·09			·06	·08			·06							·10						·19		2·43
DuBois,		·03	·51				·22	·57		·31	·06	·06	·04				·11							·15						·21		2·27
Elwood Junction,	·10		·30		·21	·22		·52		·13	·04	·03	·05	·03			·10							·02					·01	·12		1·88
Freeport,			·46	·05	·24	·05		·51	·02	·12	·10	·12	·10	·12	·03		·07			·02				·12	·03	·01		·01		·28		2·45
Greensboro,	·02		·45		·38	·25	·02	·10	·08		05						·50	·06						·20						·20		2·31
Greenville,				·14	·01	·03	·15	·04	·04	·50	·20	·03								·40				40	·23	·30						2·47
(Immel Reservoir)																																
Lycippus,			·45		·50			·34	·06	·15							·20													·75		2·45
Johnstown,			·36		·48	·02	·30	·20	·05	·12	·04	·01					·06		·03				·20		·04	·02		·02		·60		2·55
Kane,																																
Ligonier,																																
Lock No. 4,	·04		·25		·34	·13	·07	·33	·03	·08	·03	·03		·04	·02		·15							·16						·57		2·37
Mahoning,	·02		·32		·26	·08	·03	·47	·05	·13	·06	·05	·05	·14	·04		·02							·10		·01				·20		2·05
Oil City,	·01		·29		·24	·24	·02	·24	·02	·23	·14	·05	·10	·15	·01		·06		·04	·02			·06	·07	·05	·05			·02	·11		2·22
Parker's Landing,	·04		·35	·01	·55	·01	·03	·44	·05	·24	·13	·07	·08	·12	·03		·10		·02	·03				·11	·03	·02				·18		2·64
Pittsburg,†			25		·30	·05	·11	·29	·04	·04			·10	·01			·06		·01				·08		·01			·01		·44		1·80
Ridgway,			50		·25	·06		·19	·04	·12	·06		·04	·06			·05							·12	·02					·14		1·65
Saegerstown,			·35		·60			·20	·18	·27	15	·10	·15		·01		·09	·10							·33			·05		·03		2·61
Saltsburg,	·06		·40		·36	·07	·01	·37	·05	·10	·08	·01	·03	·03	·02		·12	·02						·11	·01	·02		·02		·25		2·14
Shingle House,	·02		42	·02	·23		·05	·21	·02	·07	·10		·06	·01			·06		·01				·01	·25	·30		·20	·30		·08		2·42
Smethport,			·55		·22			·30			·15		·50										·15		·30			·20		·15		2·52
Somerset,				·30	·40	·12	·40	·10	·15	·25						60									·23					·15		2·70
Stoyestown,	·23		·79		·51	·01	·18	·17	·15		·20	·18					·22							·11		·10		·05		·11		3·22
Uniontown,			25		·49	·15	·30			·17							·51						·25							·84		2·96
Warren,			·58	·01	·45	·06		·14	·02	·12	·21	·10	·20	·04	·01		·72		·10	·01			·08	·04	·53	·11		·10	·01	·10		3·64
West Newton,	·04		35		·35	·17		·41	·05	·05	·05			·03			·09	·08						·18						25		2·10
Potomac Basin.																																
Chambersburg,			·89		·20		·03			·07													·02							·07		1·28
Lake Basin.																																
Erie,†	·05		·30	·02	·78		·01	·06	·03	·17	·10	·01		·01		·01	·08		·13				·04	·01						·09		1·90

† U. S. Weather Bureau Stations. * Missing.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR NOVEMBER, 1894.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR DECEMBER, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 31, 1894.

GENERAL REVIEW.

The average temperature for December, 1894, 32°·4, is 0°·4 below the average [32°·8] for the past seven years.

The highest recorded temperatures occurred on the 15th, 16th, 17th, 21st and 22d, and were as follows: Immel Reservoir, 66°; Johnstown, 64°; Pittsburgh, 62°, and Smethport, 62°.

The lowest were on the 29th and 30th: Wellsboro, minus 28°; Shingle House, minus 25°; Emporium, minus 18°, and Towanda, minus 16°.

From January 1, 1894, to December 31, 1894, the accumulated excess in daily mean temperature at Philadelphia was 459°; at Erie, 709°, and at Pittsburgh, 580°.

For the same period the deficiency in precipitation, in inches, at Philadelphia, was 0·22; Erie, 7·55, and Pittsburgh, 9·31

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches*
December, 1887, ...	31°·5	3·53
1888, ...	32°·6	3·14
1889, ...	39°·3	2·77
1890, ...	27°·5	3·97
1891, ...	38°·6	4·09
1892, ...	27°·9	1·69
1893, ...	32°·1	3·06
1894, ...	32°·4	3·95

The means of the daily maximum and minimum temperatures, 40°·0 and 24°·9, respectively, give a monthly mean of 32°·4, which is 0°·3 above the corresponding month of 1893.

The average daily range was 15°·1.

Highest monthly mean, 37°·0 at Philadelphia, Weather Bureau.

Lowest monthly mean, 24°·7 at Selins Grove.

Highest temperature recorded during the month, 66° on the 17th at Immel Reservoir.

Lowest temperature, minus 28° on the 29th at Wellsboro.

Greatest local monthly range, 86° at Wellsboro.

Least local monthly range, 47° at South Bethlehem.

Greatest daily range, 40° at Drifton.

PRECIPITATION.

The average precipitation for the State, for the month, 3·95 inches, is 0·77 inches more than the average [3·18] for the last seven years.

General rains prevailed on the 1st, 2d, 8th, 9th, 10th, 11th, 12th, and snow on the 25th, 26th and 27th.

The storm of the 26th was a mixture of snow and sleet, and caused considerable damage to telegraph and telephone lines.

Light snow occurred at a few stations on the 1st, 2d, 9th, 10th and 11th.

The largest monthly totals of snowfall in inches were: Shingle House, 22·5; Honesdale, 21·5; Somerset, 21·0; Lock Haven, 2·10.

An average of 8·7 inches for the State remained on ground at the end of the month.

The largest monthly totals of rainfall and melted snow in inches were: Confluence, 5·93; Somerset, 5·69; Quakertown, 5·33; Pottstown, 5·32; Uniontown, 5·19, and Immel Reservoir, 5·15.

The least were: Greenville, 2·27; Altoona, 2·30; Saegerstown, 2·39; Erie, 2·53; Chambersburg, 2·65, and Oil City, 2·65.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 10; clear days, 10; fair days, 9; cloudy days, 12.

BAROMETER.

The mean pressure for the month, 30·15, is about ·09 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·52 at Pittsburgh on the 18th, and the lowest 29·25 at Philadelphia on the 27th.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—West Chester, 12th; Coatesville, 12th; Phœnixville, 12th.

Hail.—Emporium, 10th; West Chester, 26th; Grampian, 10th; Easton, 26th; Dyberry, 11.

Snow.—Hamburg, 27th; Hollidaysburg, 27th; Towanda, 1st, 10th, 27th; Quakertown, 25th, 27th; Cassandria, 24th, 25th, 27th; Johnstown, 26th, 27th, 28th; Emporium, 10th, 26th, 27th; Mauch Chunk, 25th, 27th; State College, 10th, 25th, 26th, 27th; West Chester, 26th; Coatesville, 26th, 27th; Phœnixville 26th, 27th; Kennett Square, 26th, 27th; Westtown, 26th, 27th; Grampian, 26th, 27th; Lock Haven, 25th, 26th, 27th; Saegerstown, 27th; Carlisle, 10th, 24th, 27th; Uniontown, 26th, 27th; Huntingdon, 10th, 25th, 26th, 27th; Lebanon, 25th, 26th, 27th; Coopersburg, 25th 26th, 27th; Drifton, 10th, 24th, 26th, 27th; Wilkes-Barre, 11th, 24th, 26th, 27th; Smethport, 27th; Greenville, 27th; Pottstown, 26th; South Bethlehem, 25th, 26th, 27th; Easton, 27th; Aqueduct, 24th, 26th, 27th; *Philadelphia* [Weather Bureau], 26th; [Centennial Avenue], 26th, 27th; Blooming Grove, 25th, 27th; Shingle House, 2d, 13th, 26th, 27th; Somerset, 26th, 27th; Wellsboro, 11th, 27th; Lewisburg, 9th, 25th, 27th; Dyberry, 1st, 2d, 9th, 11th, 25th, 27th; Honesdale, 1st, 11th, 25th, 27th; Salem Corners, 1st, 11th, 25th, 27th, 28th; South Eaton, 27th; York, 26th, 27th; Selins Grove, 26th, 27th.

Sleet.—Hollidaysburg, 10th, 24th; Cassandria, 10th, 25th; Johnstown, 10th, 24th; Emporium, 10th; State College, 10th; Coatesville, 27th; Kennett Square, 26th, 27th; Westtown, 27th; Lock Haven, 10th; Lancaster, 26th; Lebanon, 10th; Coopersburg, 1st, 10th, 11th, 27th; Aqueduct, 10th; *Philadelphia* [Weather Bureau], 26th; [Centennial Avenue], 26th, 27th; Somerset, 11th; Dyberry, 2d, 11th; Honesdale, 2d, 11th; York, 10th, 24th, 27th.

Coronæ.—Lebanon, 7th, 12th, 15th; Philadelphia [Centennial Avenue], 14th; York, 7th.

Solar Halo.—Philadelphia [Weather Bureau], 16th, 24th, 26th; [Centennial Avenue], 24th, 26th; Somerset, 24th.

Lunar Halo.—Lebanon, 7th, 21st; *Philadelphia* [Weather Bureau], 7th, 19th; [Centennial Avenue], 7th.

Parhelias.—Towanda, 28th, 29th.

Monthly Summary of Reports on V

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR DECEMBER, 1894.

COUNTY.	STATION.	Elevation above Sea Level (feet).	TEMPERATURE.									PRECIPITATION.				NUMBER OF DAYS.			Wind. Prevailing Direction.	OBSERVERS.
				MAXIMUM.		MINIMUM.				DAILY RANGE.										
			Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.	Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.		
Allegheny,	Pittsburgh,	820	36·6	62	16	—4	29	43·2	30·0	13·2	22	3·10	13·1	8·0	15	6	10	15	W	O. D. Stewart, W. B.
Berks,	Hamburg.	380	32·9	52	15	1	29	39·4	26·4	13·0	27	3·61	7·0	. . .	8	3	16	12	NW	William Shipe.
Berks,	Reading.[2]	280	31·9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	4·00	. . .	. . .	12	. .	. .	. .	. . .	Franklin Yager.
Blair,	Altoona (30 days),	1,181	41·1	60	16	12	29	47·8	34·4	13·4	23	2·30	. . .	. . .	10	. .	. .	. .	. . .	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	31·8	60	15	—3	29	42·0	21·6	20·4	35	4·13	13·0	10·0	10	14	3	14	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	28·6	53	16	—8	29	35·0	22·3	12·7	19	3·39	16·5	14·0	9	10	8	13	SW	G. W. T. Warburton
Bradford,	Towanda,		30·4	59	16	—16	29	38·2	22·7	15·5	30	3·07	14·5	14·0	8	11	8	12	NW	Hiram E. Bull.
Bucks,	Forks of Neshaminy[1] (27 days),	304	38·2	. .	. . .	. . .			. . .	. .		4·62	. .	. . .	9	7	14	6	W	J. C. Hilsman.
Bucks,	Quakertown,	536	32·1	52	16	1	29	40·0	24·2	15·8	29	5·33	4·0	4·0	8	7	14	10	SW	J. L. Heacock.
Cambria,	Cassandria	2,100	31·0	60	16	—8	29	36·0	25·9	10·1	26	4·04	17·0	17·0	9	9	9	13	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	34·0	64	16	—2	29	41·9	26·1	15·8	34	4·24	15·0	12·0	13	9	6	16	S	E. C. Lorentz.
Cameron,	Emporium,	1,050	30·4	59	16	—18	29	38·4	22·5	15·9	36	2·93	19·4	12·0	9	6	10	15	SW	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	31·6	57	15	1	29	39·7	23·5	16·2	33	4·05	7·5	4·0	9	14	8	9	W	F. C. Wintermute.
Centre,	State College—Agricultural Experiment Sta.,	1,191	31·4	56	15	—4	29	38·2	24·7	13·5	23	3·14	12·2	11·0	11	8	8	15	W	Prof. Wm. Frear.
Chester,	West Chester,	455	34·2	55	15	4	29	40·6	27·8	12·8	26	4·23	3·0	2·0	10	13	10	8	NW	J. C. Green, D.D.S.
Chester,	Coatesville,	380	33·5	59	15	3	29	42·8	24·2	18·6	33	4·70	5·0	4·0	11	17	8	6	W	W. T. Gordon.
Chester	Kennett Square,	275	35·0	56	16	4	29	43·4	26·6	16·8	32	4·34	4·8	3·0	10	11	10	10	NW	B. P. Kirk.
Chester.	Phœnixville,	190	34·5	59	15	2	29	42·0	27·0	15·0	30	4·17	7·5	4·5	12	11	6	14	NW	Knowles Croskey.
Chester,	Westtown (27 days),	350	33·0	53	16	5	29	39·8	26·2	13·6	26	4·36	5·0	3·5	8	9	9	9	W	John D. Carter.
Clearfield,	Grampian,	1,450	28·8	60	16	—10	29	34·6	23·0	11·6	28	3·85	19·0	8·0	10	4	17	10	W	Nathan Moore.
Clinton,	Lock Haven,[1]	560	30·8	55	16	—12	29	. . .	. . .	. . .	. . .	3·73	21·0	. . .	9	14	3	14	W	Prof. J. A. Robb.
Columbia,	Bloomsburg—State Normal School,	500	. . .	. . .	. . .	. . .	. .	. . .	. . .	. . .	. . .	. .	. . .	. . .	. . .	. .	. .	. .	. .	Prof. J. G. Cope.
Crawford,	Saegerstown,	1,200	31·4	54	16	—15	28	40·2	22·6	17·6	39	2·39	4·0	3·0	9	6	5	20	S	J. G. Apple.
Cumberland,	Carlisle,	480	31·8	50	22	—2	30	39·0	24·6	14·4	26	3·38	14·0	10·0	9	18	3	10	W	J. E. Pague.
Dauphin,	Harrisburg,	480	34·0	55	15	4	29	40·0	29·0	11·0	22	3·34	9·0	9·0	13	9	13	9	W	F. Ridgway, W. B.
Delaware,	Swarthmore—Swarthmore College,	361	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	Prof S. J. Cunningham.
Erie,	Edinboro,*[1]	190	29·4	49	8, 16	3	27	. . .	. . .	. . .	. . .	. . .	10·0	5·0	10	6	12	13	S	C. F. Sweet.
Erie,	Erie,	1,400	35·0	60	15	2	29	42·0	28·0	14·0	26	2·53	. . .	. . .	14	6	6	19	SW	P Wood, W. B.
Fayette,	Uniontown,	681	36·6	58	16, 12, 21	—5	29	43·6	29·6	14·0	29	5·19	15·0	. .	9	12	11	8	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	32·3	61	22	—3	29	40·8	23·8	17·0	29	2·65	. . .	5·0	9	15	2	14	W	J. C. Boggs.
Huntingdon,	Huntingdon—The Normal College,	650	32·6	61	15	—2	29	42·0	23·2	18·8	37	4·21	16·5	7·0	11	15	5	11	W	Prof. W. J. Swigart.
Lancaster,	Lancaster (23 days)—Franklin and Marshall Col'ge,	413	38·4	59	15	. . .	. . .	45·9	31·0	14·9	30	3·33	. . .	. .	6	13	5	5	W	A. V. Heister.
Lebanon,	Lebanon,	458	32·8	55	15	1	30	40·5	25·1	15·4	27	4·17	6·8	4·5	11	12	11	8	NW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	34·1	55	15	3	29	41·4	26·8	14·6	23	5·04	7·0	6·0	12	14	8	9	NW	Dr. M. H. Boye.
Luzerne,	Drifton (25 days),	1,683	29·8	52	1, 4, 24	—4	29	40·2	19·4	20·8	40	1·28	9·5	8·5	5	10	10	5	NW	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	32·2	53	16	—5	29	40·2	24·2	16·0	25	3·66	19·0	15·0	6	20	5	6	W	A. W. Betterly.
McKean,	Kane,	2,000	. . .	. . .	. . .		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	C. H. Kemp.
McKean,	Smethport (30 days),	1,500	29·0	62	16	—9	29	36·8	21·2	15·6	34	3·45	18·0	. . .	6	7	9	14	SW	Armstrong & Brownell.
Mercer,	Greenville—Thiel College,	1,000	32·2	54	15, 23	—8	29	40·2	24·3	15·9	28	2·27	4·0	4·0	6	13	5	13	. . .	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	34·3	56	. . .	4	29	41·6	27·0	14·6	28	5·32	6·0	3·0	7	15	9	7	NW	Charles Moore, D.D.S.
Northampton,	Bethlehem,		33·1	52	16	3	29	40·4	25·8	14·6	25	4·85	6·0	. . .	8	. .	. .	. .		J. E. Luckenbach.
Northampton,	South Bethlehem,	339	32·6	50	15, 16	3	29	38·4	20·8	11·6	23	. . .	5·5	4·0	. . .	10	8	13	NW	T. Merriman.
Northampton,	Easton—Lafayette College,	325	31·6	48	15, 16, 17	—2	29	38·0	25·2	12·8	19	3·55	4·2	4·0	8	12	10	9	. .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	34·3	56	15	1	30	42·0	26·6	15·4	36	3·79	13·4	11·0	14	11	10	10	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	37·0	56	16	7	29	42·7	31·1	11·6	21	4·03	3·0	. .	10	10	11	10	NW	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	36·9	58	16	7	29	43·1	30·7	12·4	22	4·44	4·0	2·5	10	11	11	9	NW	John Comly.
Pike,	Blooming Grove,*[1]	. . .	28·3	50	15	—8	29	. . .	. . .	. . .	. . .	4·15	12·0	10·0	11	3	17	11	W	John Grathwohl.
Potter,	Shingle House,	1,475	28·5	59	16	—25	29	37·2	19·8	17·4	35	3·21	22·5	20·0	11	7	7	17	W	C. D. Voorhees, M.D.
Snyder,	Selins Grove,	455	24·7	52	12	—10	28	32·8	16·6	16·2	29	3·76	18·0	18·0	8	3	10	8	NW	J. M. Boyer,
Somerset,	Somerset,	2,250	29·6	63	15	—13	29	39·6	19·7	19·9	31	5·69	21·0	15·0	11	4	11	16	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	27·8	58	16	—28	29			. .	. . .	4·07	18·5	18·0	6	7	7	17	S	H. D. Deming
Union,	Lewisburg	450	31·8	59	22	—14	29	41·6	22·1	19·5	37	4·06	20·0	. .	9	5	14	12	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	26·8	50	16, 21	—11	29	35·4	18·2	17·2	33	3·89	18·5	12·0	8	12	4	15	NW	Theodore Day.
Wayne,	Honesdale,	1,000	29·7	52	15	—8	29	36·5	22·9	13·6	27	4·05	21·5	11·5	8	13	10	8	NW	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	29·4	55	21	—8	29	36·8	22·0	14·8	28	4·61	16·6	10·0	14	7	8	16	W	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	34·3	66	17	—3	29	40·4	28·2	12·2	34	5·15	. . .	. . .	7	. .	. .	. .	. . .	Murray Forbes.
Westmoreland,	Ligonier,	1,750		.		. . .	. .	. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	.	C. D. Ambrose.
Wyoming,	South Eaton,	660	30·4	53	16	—5	29	38·8	22·1	16·7	27	3·41	15·0	15·0	9	12	5	14	NW	B. M. Hall.
York,	York,	385	33·2	56	15	—1	29	40·6	25·8	14·8	30	3·90	6·5	3·5	12	10	15	6	W	Mrs. L. H. Greenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 2.

3	4	5	6	7	8
. .	. .	. .	. .	. .	·15
·21	. .	. .	. .	. .	·31
. .	. .	. .	. .	. .	·41
·05	. .	. .	. .	. .	·31
·22	. .	. .	. .	. .	·22
·02	. .	. .	. .	. .	·10
·69	. .	. .	. .	. .	·19
. .	. .	. .	. .	. .	·22
·10	. .	. .	. .	. .	·18
·10	. .	. .	. .	. .	·20
. .	. .	. .	. .	. .	·36
. .	. .	. .	. .	. .	·59
. .	. .	. .	. .	. .	·60
. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .
·02	. .	. .	. .	. .	·08
·05	. .	. .	. .	. .	·22
. .	. .	. .	. .	.	·14
·03	. .	. .	. .	. .	·32
. .	. .	. .	. .	. .	·45
. .	. .	. .	. .	. .	·11
. .	. .	. .	. .	. .	·30
·03	. .	. .	. .	. .	·08
. .	. .	. .	. .	. .	·05
. .	*	. .	. .	. .	·15
. .	. .	. .	. .	. .	·38
. .	. .	. .	. .	·01	·91
. .	. .	. .	. .	. .	·54
·07	. .	. .	. .	. .	·12
·10	. .	. .	. .	. .	·04
. .	. .	. .	. .	. .	·24
. .	. .	. .	. .	. .	·08

PRECIPITATION DURING DECEMBER, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin																																
Bethlehem, ...	·26	·59	. .	. .	. .	. .	. .	·54	. .	. .	·53	1·25	. .	. .	. .	·02	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	1·64	. .	. .	. .	. .	4·85
Blooming Grove, .	‡	·93	. .	. .	. .	. .	. .	‡	·63	‡	‡	1·50	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	‡	·20	‡	·89	. .	. .	. .	. .	4·15
Browers Lock, . . .	·16	·17	. .	. .	. .	. .	. .	·42	·13	. .	·59	1·04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·06	. .	·85	. .	. .	. .	. .	3·42
Coatesville, ...	·28	·17	. .	. .	. .	. .	. .	·48	·01	·31	·30	1·72	. .	. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	·18	·35	·85	. .	. .	. .	. .	4·70
Coopersburg, ...	·29	·56	. .	. .	. .	. .	. .	·53	·01	·06	·53	1·44	. .	. .	. .	. .	·02	. .	. .	. .	. .	·01	. .	. .	·22	·21	1·16	. .	. .	. .	. .	5·04
Doylestown, ...	·11	·19	. .	. .	. .	. .	. .	·58	·03	. .	·29	1·57	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1·12	. .	. .	. .	. .	3·89
Dyberry, ...	·07	·65	. .	. .	. .	. .	. .	·30	·50	. .	·35	·60	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·30	. .	1·12	. .	. .	. .	. .	3·89
Easton, ...	·22	·50	. .	. .	. .	. .	. .	. .	·43	. .	. .	1·90	. .	. .	. .	. .	·01	. .	. .	. .	. .	·01	. .	. .	03	. .	·45	. .	. .	. .	. .	3·55
Forks of Nesnaminy, .	·40	·25	. .	. .	. .	. .	. .	·79	. .	·07	·40	1·27	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .	·14	. .	1·27	. .	. .	. .	. .	4·62
Frederick, ...	·35	·35	. .	. .	. .	. .	. .	·43	. .	·09	·39	2·24	. .	. .	. .	·04	. .	. .	. .	. .	. .	. .	. .	. .	·15	·08	·92	. .	. .	. .	. .	5·04
Hamburg, ...	·36	·68	. .	. .	. .	. .	. .	·41	. .	. .	40	1·00	. .	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	·18	. .	·56	. .	. .	. .	. .	3·61
Honesdale, ...	·14	·68	. .	. .	. .	. .	. .	·51	·09	. .	·42	37	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·30	. .	1·48	. .	. .	. .	. .	4·05
Kennett Square, . . .	·25	·14	. .	. .	. .	. .	. .	·45	·02	·18	·62	·85	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·18	1·15	·50	. .	. .	. .	. .	4·34
Lansdale, ...	·13	·60	. .	. .	. .	. .	. .	·32	·20	·21	·26	1·17	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·13	·90	. .	. .	. .	. .	3·92
Mauch Chunk, . . .	·23	·70	·03	. .	. .	. .	. .	·27	·19	. .	·52	·62	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·34	. .	1·15	. .	. .	. .	. .	4·05
Ottsville, ...	·24	·47	. .	. .	. .	. .	. .	·47	·39	. .	27	2·00	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·08	. .	·86	. .	. .	. .	. .	4·78
Philadelphia, n† . .	·23	·09	. .	. .	. .	. .	. .	·49	·03	·07	·53	1·10	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·14	·15	1·20	. .	. .	. .	. .	4·03
Philadelphia, h, . . .	·23	·10	. .	. .	. .	. .	. .	·50	·01	·08	·54	1·12	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·14	·23	1·49	. .	. .	. .	. .	4·44
Phœnixville, ...	·18	·20	. .	. .	. .	. .	·02	·54	·02	·13	·50	1·46	. .	. .	. .	·03	. .	. .	. .	. .	. .	. .	. .	·16	. .	·12	·81	. .	. .	. .	. .	4·17
Point Pleasant, . . .	·21	·11	. .	. .	. .	. .	. .	·56	·11	·19	·31	1·33	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·12	·12	1·18	. .	. .	. .	. .	4·14
Pottstown, ...	·25	·25	. .	. .	. .	. .	. .	·45	. .	. .	·67	1·80	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·20	1·70	. .	. .	. .	. .	. .	5·32
Quakertown, ...	·36	·45	. .	. .	. .	. .	. .	. .	·19	. .	·90	2·35	. .	. .	. .	·06	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	1·00	. .	. .	. .	. .	5·33
Reading, ...	·15	·50	. .	. .	. .	. .	. .	·30	·03	·15	·34	1·25	. .	. .	. .	. .	·01	. .	. .	. .	. .	·01	. .	. .	·04	·15	1·07	. .	. .	. .	. .	4·00
(Salem Corners) Hamlinton, ...	·31	·75	·09	. .	. .	. .	. .	·20	·47	·06	·34	·71	·07	. .	. .	. .	·02	. .	. .	. .	. .	·04	. .	. .	·15	. .	1·30	·10	. .	. .	. .	4.61
Seisholtzville, ...	·37	·52	. .	. .	. .	. .	. .	·46	. .	·05	·66	1·35	. .	. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	·15	·14	·83	. .	. .	. .	. .	4·58
Smith's Corner, . . .	·27	·41	. .	. .	. .	. .	. .	·59	·04	·07	·32	1·41	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·13	·07	·75	. .	. .	. .	. .	4·06
Swarthmore, ...	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
West Chester, ...	·28	·18	. .	. .	. .	. .	. .	·48	·03	·26	·41	·85	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·10	·36	1·28	. .	. .	. .	. .	4·23
Westtown, ...	·30	·20	. .	. .	. .	. .	. .	·50	. .	·25	·35	·85	. .	*	*	. .	. .	. .	. .	. .	. .	*	. .	. .	·15	. .	1·76	. .	. .	. .	*	4·36
Susquehanna Basin.																																
Altoona, ...	·24	·44	. .	. .	. .	. .	. .	·02	·33	. .	·28	·23	·02	. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	·13	. .	·56	. .	. .	. .	. .	2·30
(Aqueduct) Logania, .	·36	·54	. .	. .	. .	. .	. .	·33	·07	·27	·20	·41	. .	. .	. .	·03	·01	. .	. .	. .	·01	. .	. .	·09	·22	·47	·78	. .	. .	. .	. .	3·79
Bloomsburg, ...	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Carlisle, ...	. .	·20	. .	. .	. .	. .	. .	·15	·20	·15	·85	·53	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·10	·10	. .	1·10	. .	. .	. .	. .	3·38
Drifton, ...	. .	*	. .	. .	. .	. .	. .	·33	*	·10	. .	. .	. .	. .	. .	*	. .	. .	. .	. .	. .	. .	*	·20	*	·60	·05	. .	. .	*	. .	1·28
Emporium, ...	·40	. .	. .	. .	. .	. .	. .	·40	. .	·02	. .	·45	·02	. .	. .	·10	. .	. .	. .	. .	. .	. .	. .	. .	·09	·05	1·40	. .	. .	. .	. .	2·93
Girardville, ...	·24	·18	. .	. .	. .	. .	. .	·76	. .	·12	·20	·33	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·34	·18	·80	1·60	. .	. .	. .	. .	4·75
Grampian, ...	·55	·33	. .	. .	. .	. .	. .	·34	. .	·36	. .	·55	. .	. .	. .	·08	. .	. .	. .	. .	·04	. .	. .	·10	·20	. .	1·30	. .	. .	. .	. .	3·85
Harrisburg,†	·44	·50	. .	. .	. .	. .	. .	·32	·03	·30	·27	·48	·01	. .	. .	·06	. .	. .	. .	. .	. .	·01	. .	. .	·13	·08	·71	. .	. .	. .	. .	3·34
Hollidaysburg, . . .	·33	·60	. .	. .	. .	. .	. .	·48	. .	·30	·07	·42	. .	. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	·06	·66	1 16	. .	. .	. .	. .	4·13
Huntingdon, ...	·37	·58	. .	. .	. .	. .	. .	·45	. .	·36	·07	·63	. .	. .	. .	·04	·06	. .	. .	. .	. .	. .	. .	. .	·25	·30	1·10	. .	. .	. .	. .	4·21
Kilmer, ...	. .	1·12	. .	. .	. .	. .	. .	·34	. .	. .	·95	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·25	. .	. .	1·30	. .	. .	. .	. .	3·96
Lancaster, ...	·29	·26	. .	. .	. .	. .	. .	·74	. .	·30	·49	1·25	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	*	*	*	*	*	*	*	*	3·33
Lebanon, ...	·33	·56	. .	. .	. .	. .	. .	·37	·14	·28	·30	·67	. .	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	·09	·90	·51	. .	. .	. .	. .	4·17
Le Roy, ...	·16	·52	. .	. .	. .	. .	. .	·53	·05	. .	·45	·15	. .	. .	. .	. .	·02	. .	. .	. .	·11	. .	. .	. .	. .	. .	1·40	. .	. .	. .	. .	3·39
Lewisburg, ...	·12	·60	. .	. .	. .	. .	. .	·34	·10	. .	·60	·35	. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	. .	·10	. .	1·80	. .	. .	. .	. .	4·06
Lock Haven, ...	·40	·50	. .	. .	. .	. .	. .	·03	. .	·05	·20	·45	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·10	·60	1·40	. .	. .	. .	. .	3·73
Selins Grove, ...	·18	·63	. .	. .	. .	. .	. .	·59	·10	·37	·09	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·40	1·40	. .	. .	. .	. .	3·76
South Eaton, ...	·18	·49	. .	. .	. .	. .	. .	·44	·10	. .	·34	·28	. .	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	·05	. .	1·50	. .	. .	. .	. .	3·41
State College, ...	·30	·48	. .	. .	. .	. .	. .	·33	·03	·20	·19	·43	. .	. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	·03	·40	·70	. .	. .	. .	. .	3·14
Towanda, ...	·08	·49	. .	. .	. .	. .	. .	·66	·05	·19	.	·17	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .	. .	. .	1·40	. .	. .	. .	. .	3·07
Wellsboro, ...	. .	·10	. .	. .	. .	. .	. .	·02	. .	·10	·05	2·00	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1·80	. .	. .	. .	. .	4·07
Wilkes-Barre, ...	. .	. .	. .	. .	. .	. .	. .	1·03	. .	. .	·20	·71	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·22	. .	‡	1·50	. .	. .	. .	. .	3·66
York, ...	·34	·29	. .	. .	. .	. .	. .	·38	·02	·25	·55	·67	. .	. .	. .	·04	. .	. .	. .	. .	. .	·04	. .	. .	·15	·17	1·00	. .	. .	. .	. .	3·90

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam, ...	·42	·48	. .	. .	. .	. .	. .	·15	·02	. .	·36	·19	·20	. .	. .		·48	. .	. .	. .	. .	. .	. .	. .	·91	. .	·38	·03		. .	. .	3·62
Brookville, ...	·11	·47	·21	. .	. .	. .	. .	·31	·17	. .	·35	·23	·56	. .	. .		·19	. .	. .	. .	. .	. .	. .	. .	·24	. .	1·54	·10	. .	. .	. .	4·48
Cassandria, ...	·28	·96	. .	. .	. .	. .	. .	·41	. .	·12	·11	·15	. .	. .	. .	·03	. .	. .	. .	. .	. .	. .	. .	. .	·28	.	1·70	. .	. .	.	.	4·04
Clarion, ...	·29	·44	·05	. .	. .	. .	. .	·31	·07	. .	·41	·11	·63	·02	. .	. .	·15	. .	. .	. .	. .	. .	. .	. .	·33	. .	1·08	·05	.	.		3·94
Confluence, ...	·45	·95	·22	. .	. .	. .	. .	·22	·60	. .	·30	·20	·19	. .	. .	. .	·18	. .	. .	. .	. .	. .	. .	. .	·56	·04	1·77	·25	. .	. .	. .	5·93
Davis Island Dam, .	·42	·64	·02	. .	. .	. .	. .	·10	·20	. .	·36	·19	·12	. .	. .	. .	·03	. .	. .	. .	. .	. .	. .	. .	·42	. .	1·20	·10	. .	.	.	3·80
DuBois, ...	. .	·22	·69	. .	. .	. .	. .	·19	·12	. .	·18	·12	·38	·14	. .	. .	·12	. .	. .	. .	. .	·04	. .	. .	·14	·04	·76	·08	. .			3·22
Elwood Junction, . .	·39	·51	. .	. .	. .	. .	. .	·22	·01	. .	·22	·15	·16	. .	. .	. .	·04	. .	. .	. .	. .	. .	. .	. .	·51	·03	·50	·01	. .	. .	.	2·75
Freeport, ...	·38	·70	·10	. .	. .	. .	. .	·18	. .	. .	·42	·20	·23	. .	. .	. .	·11	. .	. .	. .	. .	. .	. .	. .	·60	. .	1·00	·06	. .	. .	. .	3·98
Greensboro, ...	·45	·80	·10	. .	. .	. .	. .	·20	·25	. .	·15	·10	·45	. .	. .	. .	·15	. .	. .	. .	. .	. .	. .	. .	·35	·02	·65	. .	. .	. .	.	3·67
Greenville, ...	. .	. .	. .	. .	. .	. .	. .	·36	. .	. .	·30	·38	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·35	·60	·28	.		.	.	2·27
(Immel Reservoir) Lycippus, ...	. .	1·20	. .	. .	. .	. .	. .	·59	. .	·18	. .	·50	. .	. .	. .	·21	. .	. .	. .	. .	. .	. .	. .	. .	·47	. .	2·00	. .	. .	. .		5·15
Johnstown, ...	·53	·68	. .	. .	. .	. .	. .	·60	. .	·30	·01	·26	. .	. .	. .	·05	·05	. .	. .	. .	·01	. .	. .	·03	·41	·40	·91	. .	. .	. .	. .	4·24
Kane, ...	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .
Ligonier, ...	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .		
Lock No. 4, ...	·25	·95	·02	. .	. .	. .	. .	·08	·19	. .	·25	·10	·07	. .	. .	. .	·08	. .	. .	. .	. .	. .	. .	. .	·40	. .	1·10	·07	. .	.	. .	3·56
Mahoning, ...	·48	·73	·05	. .	. .	. .	. .	·22	·04	. .	·50	·14	·30	. .	. .	. .	·12	. .	. .	. .	. .	·01	.	. .	·61	·01	1·12	·20	. .			4·53
Oil City, ...	·13	·30	. .	. .	. .	. .	. .	·14	·02	. .	·38	·12	·40	. .	. .	. .	·10	. .	. .	. .	. .	. .	. .	. .	·24	. .	·80	·02	. .	. .		2·65
Parker's Landing, . .	·34	·42	·03	. .	. .	. .	. .	·32	·04	. .	·40	·18	·34	. .	. .	. .	·06	. .	. .	. .	. .	. .	. .	. .	·32	. .	1·00	·09	. .	. .	.	3·54
Pittsburg,†	·37	·43	. .	. .	. .	. .	. .	·45	·06	·26	·02	·25	·01	. .	. .	·01	·02	. .	. .	. .	·01	. .	. .	·16	·15	·24	·66	. .	. .		. .	3·10
Ridgway, ...	·10	·42	. .	. .	. .	. .	. .	·11	·03	. .	·27	·10	·26	. .	. .		·15	. .	. .	. .	. .	. .	. .	. .	·10	. .	1·58	·11	. .	.		3·23
Saegerstown, ...	·25	·08	. .	. .	. .	. .	. .	·30	. .	·20	·20	·60	·14	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·25	. .	·37	.	.		. .	2·39
Saltsburg, ...	·36	·87	·03	. .	. .	. .	. .	·08	·63	. .	·26	·08	·25	. .	. .	. .	·08	. .	. .	. .	. .	·01	. .	. .	·57	. .	1·00	·25	.			4·47
Shingle House, . . .	·12	·29	. .	. .	. .	. .	. .	·05	. .	. .	·20	·20	·05	. .	. .	·08	·02	. .	. .	. .	. .	. .	. .	. .	·05	·15	2·00	. .	. .			3·21
Smethport, ...	·40	·30	. .	*	. .	. .	. .	·15	. .	. .	. .	·60	. .	. .	. .	. .	·20	. .	. .	. .	. .	. .	. .	. .	. .	. .	1·80	. .	.			3·45
Somerset, ...	. .	1·25	. .	. .	. .	. .	. .	·38	. .	·25	·15	. .	. .	·26	. .	. .	. .	. .	. .	. .	. .	. .	. .	1·15	. .	1·05	1·20	.	. .	.	.	5·69
Stoyestown, ...	·33	. .	. .	. .	. .	. .	·01	·91	. .	·31	·36	·10	·12	. .	. .	. .	·26	. .	. .	. .	. .	. .	. .	·37	. .	·10	1·50	·20	. .	. .	. .	4·57
Uniontown, ...	·73	·96	. .	. .	. .	. .	. .	·54	. .	·14	. .	·55	. .	. .	. .	·08	. .	. .	. .	. .	. .	. .	. .	. .	·69	·50	1·00	. .	. .	. .		5·19
Warren, ...	·03	·38	·07	. .	. .	. .	. .	·12	·04	.	·36	·06	·27	. .	. .	. .	·29	. .	. .	. .	. .	. .	. .	.	·04	·01	1·18	·02	. .	.	.	2·87
West Newton, ...	·45	·92	·10	. .	. .	. .	. .	·04	·48	. .	·20	·06	·26	.	. .	. .	·14	. .	. .	. .	. .	·02	. .	. .	·50	. .	1·60	·10	. .		.	4·87
Potomac Basin.																																
Chambersburg, . . .	·25	·18	. .	. .	. .	. .	. .	·24	. .	·37	·15	·72	. .	. .	. .	. .	.	. .	. .	. .	. .	. .	. .	. .	·02	·27	·45	. .	. .	.		2·65
Lake Basin.																																
Erie,†	·22	·08	. .	. .	. .	. .	. .	·08	. .	·08	·10	·56	·02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·06	·04	. .	·86	·13	·00	·16	·12	[illegible]

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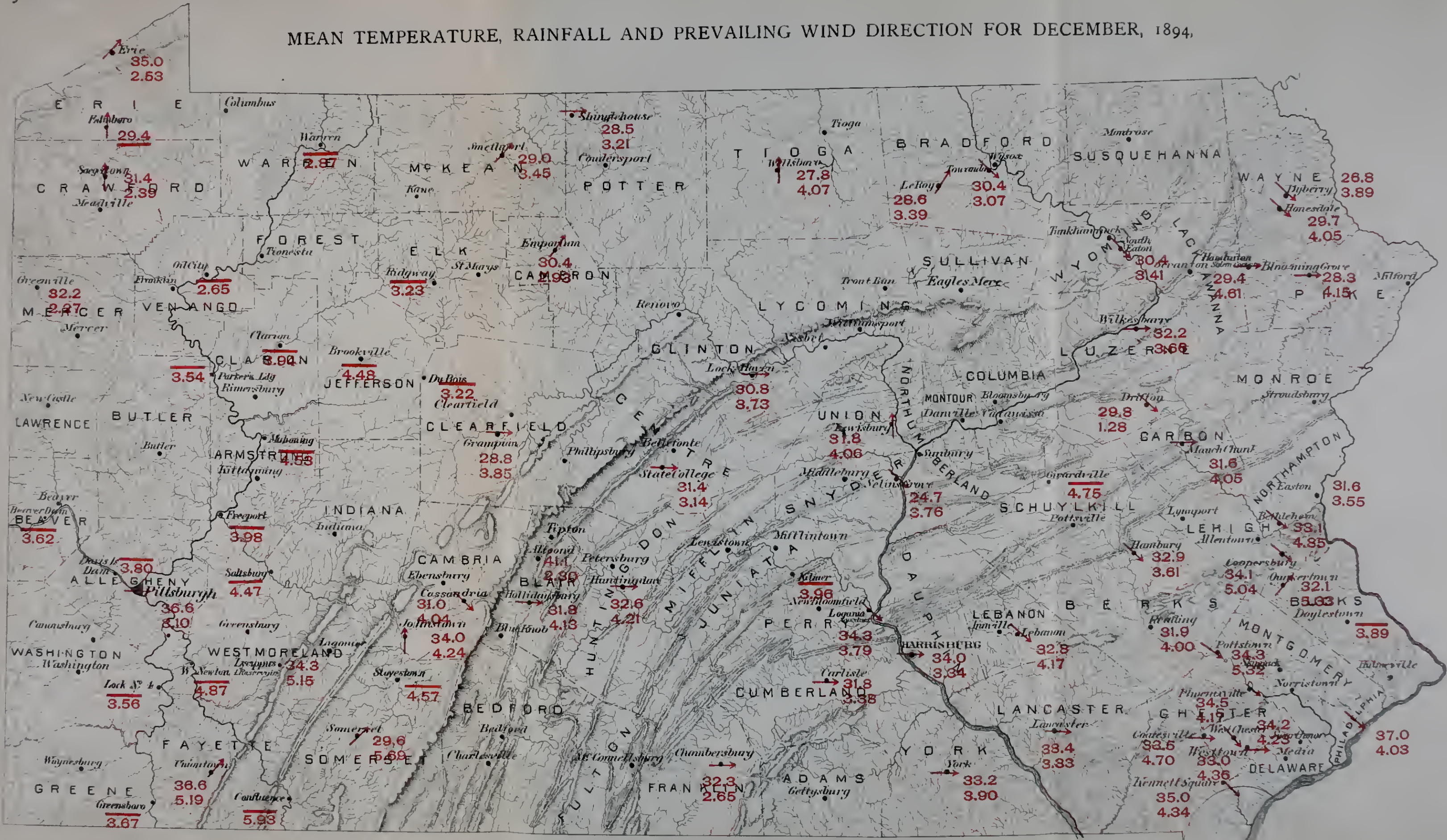
†U. S. Weather Bureau Stations. *Missing ‡Amount included in measurement following.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR DECEMBER, 1894.



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